Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [x] Coloured covers/ Couverture de couleur
- [ ] Covers damaged/ Couverture endommagée
- [ ] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

- [x] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [ ] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [ ] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [ ] Quality of print varies/ Qualité inégale de l'impression
- [ ] Continuous pagination/ Pagination continue
- [ ] Includes index(es)/ Comprend un (des) index

Title on header taken from:/ Le titre de l'en-tête provient:

- [ ] Title page of issue/ Page de titre de la livraison
- [ ] Caption of issue/ Titre de départ de la livraison
- [ ] Masthead/ Générique (périodiques) de la livraison

- [ ] Additional comments:/ Commentaires supplémentaires:

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X		12X		14X		16X		18X		20X		22X		24X		26X		28X		30X		32X
														/								

9

REPORT

ON A

NEW WATER SUPPLY

FOR THE

CITY OF WINNIPEG

MANITOBA

BY

BOARD OF CONSULTING ENGINEERS

AUGUST 29, 1907

REPORT

ON A

NEW WATER SUPPLY

FOR THE

CITY OF WINNIPEG

MANITOBA

ADDENDA

In connection with estimates furnished on page 34 of our report, we desire to state that figures given refer to the development of a ground water supply in the district twelve miles north of the city, referred to in second paragraph, page 33.

James H. Fuertes
R. S. Lea
J. E. Schwitzer
George C. Whipple

WINNIPEG:
The Telegram Printing Co. Ltd.
1907

REPORT

ON A

NEW WATER SUPPLY

FOR THE

CITY OF WINNIPEG

MANITOBA

BY

JAMES H. FUERTES, R. S. LEA,
J. E. SCHWITZER, GEORGE C. WHIPPLE,
Board of Consulting Engineers,

AUGUST 29, 1907.

WINNIPEG:
THE TELEGRAM PRINTING CO. LTD.
1907

WINNIPEG WATER SUPPLY COMMISSION.

Mayor James H. Ashdown, *Chairman*.
Controller J. G. Harvey.
Alderman J. C. Gibson.
Alderman A. A. McArthur.
Alderman A. H. Pulford.
Alderman D. McLean.
T. R. Deacon, Esq.
Dr. R. M. Simpson.
Andrew Strang, Esq.
A. L. Johnson, Esq.

WATER COMMISSION.

To His Worship the Mayor and City Council, Winnipeg, Man.:

The Water Supply Commission of the City of Winnipeg was authorized by special Act of the Manitoba Legislature as follows (Cap. 95, Sub-sec. 930A):

"The Council may pass a by-law appointing a commission, consisting of the mayor, four aldermen and three citizens and the Chairman of the Provincial Board of Health, to be known as the 'Water Supply Commission,' which shall investigate the best available sources of water supply for the city, and report such investigation or investigations to the Council. The members of such commission shall receive no remuneration for their services, beyond their travelling and personal expenses incurred under the authority of the Commission and the Council, but said Commission may employ such expert engineering and clerical assistance with the approval of the Council as the Commission may direct, and the cost and expense of same shall be borne by the City."

Acting under the foregoing authority the City Council, by by-law passed July 23, 1906, made the following appointments as members of the Commission: Thos. Sharpe (Mayor), Ald. A. A. McArthur, Ald. J. G. Harvey, J. H. Ashdown, Esq., Andrew Strang, Esq., Ald. J. C. Gibson, Ald. H. Sandison, Dr. R. M. Simpson (Chairman Provincial Board of Health), T. R. Deacon, Esq., C.E.

J. H. Ashdown was elected Chairman of the Commission, and the policy decided upon was that the Commission should personally examine the probable sources of supply and collect data bearing on the same, and accompanied by Col. H. N. Ruttan, City Engineer, they visited and inspected the following sources:—

The present well system and old Assiniboine pumping plant;

A test well near the Assiniboine River, west of Sturgeon Creek;

Poplar Springs, located on section one, township fourteen, range two east;

Crystal Springs, located on section twenty-six, township fifteen, range three east;

Rosseau River, about forty-five miles in a direct line from Winnipeg;

Springs on Logan Avenue, about four miles west of Canadian Pacific Railway shops;

Lake Manitoba, adjacent to Oak Point;

Shoal Lake, tributary to Lake of the Woods;

Winnipeg River, in vicinity of Lac du Bonnet Station.

From the various analyses of water and estimates of quantities available, a number of these sources were eliminated from further consideration, and the following were selected to be more fully investigated: Artesian well system, Red River, Shoal Lake, Winnipeg River.

At this period in the work of the Commission, the aldermanic year of the City Council terminated, and the following members of the Commission retired: Thomas Sharpe (Mayor), Ald. J. G. Harvey, Ald. H. Sandison and Mr. J. H. Ashdown, and on January 7th, 1907, after the election of the new Council for 1907, Controller J. G. Harvey, Ald. McLean, Ald. Pulford and Mr. A. L. Johnson were appointed to fill the vacancies. His Worship the Mayor, J. H. Ashdown, by virtue of his office, being also member of the Commission, was elected Chairman.

The Commission found that no accurate data were available showing the topography of the country immediately west of Shoal Lake, to assist in ascertaining the feasibility of bringing a supply from that source by gravity pipe line. Consequently, it was found necessary to make somewhat extensive surveys through that part of the country extending about thirty miles westward from Shoal Lake; and to obtain the required information, several months were occupied in carrying surveys westward to connect with data available from records of the Provincial Government drainage surveys, and the profile thus obtained demonstrated that a gravity line was quite practicable without any heavy rock cutting.

It was thereupon decided by the Commission to engage the services of a board of skilful and experienced engineers who would be chosen for their special knowledge and ability in the several features and engineering problems which would appear in the consideration of a work of this magnitude.

Messrs. A. L. Johnson and T. R. Deacon, C.E., were appointed a sub-committee to make enquiry and report to the Commission such names of engineers as from reputation and experience were specially fitted for the work; and after a large amount of correspondence and consideration of many names of those eminent in the engineering profession in Canada and the United States, the following were submitted to the Commission by the sub-committee with a recommendation for their appointment, which was adopted: J. H. Fuertes, C.E., of New York City; G. C. Whipple, C.E., of the firm of Hazen & Whipple, Consulting Engineers, New York City; R. S. Lea, C. E., of Montreal;

J. E. Schwitzer, C.E., Assistant Chief Engineer, Canadian Pacific Railway.

These gentlemen met the members of the Water Supply Commission on June 10th, in the City of Winnipeg, and after the object and scope of the Commission had been outlined to them, they were instructed to report on the following sources with a view of meeting the immediate and future needs of the city up to a population of 500,000: Artesian well system; Shoal Lake, tributary to the Lake of the Woods; Winnipeg River; Red River.

The Board of Engineers immediately took up the matter, and on August 29th, 1907, handed in the accompanying report, which is incorporated herewith, recommending the Winnipeg River as the best source for an adequate and permanent supply; and your Commission, in view of the necessity of, and the advantages that would accrue to the City of Winnipeg in being supplied with, an abundant quantity of pure, soft water, recommend that the report of the Board of Engineers be acted upon, and that the necessary steps be taken and provision made as early as possible for the carrying out of the same, in order to obtain our future requirements from the Winnipeg River, which the Board of Engineers state, on page 61 of their report, would very closely approach the requirements of an ideal water supply.

Their recommendation is to make provision immediately for the necessary pumping and filter capacities for twelve million gallons daily, and single pipe line and reservoir capacities for seventeen million gallons daily, and after the construction of the first pumping and filter units, and the completion of the first pipe line, that further pumping and filter units, together with additional pipe lines, be provided for from time to time as the daily consumption of water demands.

Your Commission further recommend that a start be made towards accomplishing this work without delay, as it is felt that no time should be lost, owing to its having been pointed out by the Board of Engineers that it will take at least three years to complete one pipe line, a year of which will be consumed in office and field work preliminary to construction. This will bring the date of completion of one pipe line to the latter part of the year 1910.

Your Commission also recommend that the extension of the present well system be proceeded with as rapidly as possible, as outlined by the Board of Engineers, to provide for the temporary requirements of the City for the period pending the completion of one pipe line from the Winnipeg River, but not to include any additions to the present softening plant, the latter not being a permanent requirement. We desire to clearly point out that such extensions of the well should not interfere with the policy of providing for the permanent supply from Winnipeg River being immediately determined upon and carried into effect.

The views held by the Board of Consulting Engineers bearing on a departure from the well systems, particularly with regard to the quality of the water, can be found on pages 29, 33, 56, 57, 60, 65 and 66 of their report.

Appended hereto is a statement showing the cost of the work accomplished by the Commission up to date.

Actual travelling expenses of the Commission, including hire of vehicles and railway fares; obtaining analyses of water; printing, postage, stationery, telegrams, maps, etc........	...$ 767.06
Fees and travelling expenses of Board of Consulting Engineers	... 10,686.13
Expense of topographical surveys from Shoal Lake by C. E. Millican, C.E., including outfit, provisions, wages of staff and transportation covering a period of about three months......	... 3,836.97
	$15,290.16

Respectfully submitted,

J. H. Ashdown, *Chairman.*
A. L. Johnson,
Andrew Strang,
T. R. Deacon,
Ald. D. McLean,
Ald. J. C. Gibson,
Contr. J. G. Harvey,
Dr. R. M. Simpson,
Ald. A. H. Pulford,
Ald. A. A. McArthur.

J. M. Miller, *Secretary.*

Winnipeg, October 30th, 1907.

TABLE OF CONTENTS

Part IV.

Part V.

Part VI.

Appendix A.

Appendix B.

Appendix C.

Analyses of Water.

APPENDIX D.

LIST OF PLATES.

SUMMARY OF CONCLUSIONS

NEW YORK, N.Y., Aug. 29, 1907.

To His Worship the Mayor, and the Water Commission of the City of Winnipeg, Canada.

GENTLEMEN,—Acting under instructions received from your Commission that we, as a board of Consulting Engineers, investigate and report upon the relative merits of four possible future sources of water supply for the City of Winnipeg, viz.:

The Red River,
The Winnipeg River,
Shoal Lake,
The Extension of the Present Ground Water Supply,

and that we advise which one would be most advantageous for the city to adopt, basing our investigations on ultimately supplying a population of 500,000 people, we herewith present the results of our studies for your consideration.

We have been asked to refer specifically to the quantity of water available at the different sources, to the quality of water before and after treatment, to the cost of the various projects and to the time required for installing the works in each case.

In pursuance of these instructions we met in Winnipeg with your Commission on June 10th and again on June 22nd, in the meantime having visited the four sources of supply, collecting for analysis samples of the different waters, and gathering together for future use all available maps, surveys, reports and other pertinent data.

At our last conference, held in New York City, in August, we completed our investigations and formulated our recommendations in the report which we now respectfully present.

GENERAL SUMMARY.

1. The present population of Winnipeg is about 111,000. We estimate, for purposes of calculation, that this will increase to 250,000 in 10 years and to 500,000 in 25 years.

2. The present water consumption is about four million imperial gallons per day. This is abnormally low and is due partly to the poor quality of the water and partly to the small amount of manufacturing, but chiefly to a deficiency of supply.

3. The present water consumption is about 32 gallons per capita daily. As the city grows this will and ought to increase. We estimate that when the population reaches 500,000 the per capita consumption will be at least 85 gallons per day, and that the city will then need a supply of 42,500,000 gallons of water daily. This estimate assumes that the system of selling water by meter measurement is continued.

4. The quantity of water available for fire service in case of a conflagration is far too small, and the present fire risks are great. The new high pressure supply will materially improve the situation in the

district covered by it, but it will not take the place of an ample supply for the entire city.

5. The city needs an immediate increase of its water supply to take care of the natural growth in population until a new supply can be obtained. Additional water can be obtained with the least delay, by the continued development of the present well system, and we recommend that such development be rapidly pushed until a capacity of 7 to 8 million gallons a day is reached. The works should be designed and constructed for temporary use only.

6. It would not be prudent to install new works for a population of 500,000 at the present time. The capacity immediately required, if taken from the Red River, should be sufficient for an average daily consumption of at least 12,000,000 gallons; but if the water were brought from a distant source it would be prudent to provide pipes capable of supplying an average daily consumption of 17,000,000 instead of 12,000,000 gallons.

7. The water pressure in the city should be at least 70 lbs. per square inch instead of 20 or 25, as at present.

8. The quality of the ground water near Winnipeg is such that even after softening it would not be a good boiler water; and the quantity that could be safely depended upon is very uncertain. This source should therefore be considered as suitable merely for a temporary supply.

9. It is possible that ground water might be obtained from the region north of the city, near Poplar Springs; but the quantity of such water available is unknown, and probably limited, while the expenses of operation of a supply from that region would alone condemn such a project.

10. After having carefully considered the subject, we recommend that the present ground water supply be used only until a new supply can be obtained from another source, but that for several years after a new supply is introduced the old works be retained as a reserve supply.

11. In natural quality, the other three water supplies stand in the following order of excellence: Shoal Lake, Winnipeg River and Red River. All of these waters require treatment; the Winnipeg River water and Indian Bay water need decolorization and the Red River water needs clarification and softening. The Red River water needs purification also for sanitary reasons. The other two sources are better in the latter respect, and Shoal Lake is the better of the two. After being subjected to their proper treatment we place the three sources of water supply in the following order of excellence: Winnipeg River, Shoal Lake and Red River.

12. From whatever source the new supply is derived it would be best and cheapest to re-pump the water in the city and to maintain there a reservoir large enough to provide for fire service, and for the ordinary fluctuations of consumption. We recommend that the present pumping station and reservoir at McPhillips Street be retained and enlarged as may be necessary and that this station be made the central point for purification and distribution.

13. It is possible to obtain a supply of water by gravity from Shoal Lake and avoid all pumping, but as the project would involve the construction of conduits of large size capable of standing heavy pressures, the great cost of such works would render the project inadvisable.

14. A supply of water from Shoal Lake, brought to a reservoir in the city and there purified and pumped, would furnish an admirable system for the city, but as the slight advantages of this project over the others are not commensurate with the greater cost, we advise against it.

15. The Red River water filtered and softened would require the least initial outlay and would furnish a satisfactory supply. It would, however, be the most expensive and troublesome plant to operate and the water would be less satisfactory in quality than the other waters; consequently we advise against it.

16. The Red River water filtered, but not softened, would not furnish a satisfactory supply, and we advise against it.

17. We are of the opinion that it would be best and cheapest in the end for the city to go to the Winnipeg River for its new supply. This source is ample for a supply for all time and the water when filtered would be of better quality than that furnished by any of the other supplies.

18. The works necessary for the first installation would include an intake and pumping station at Winnipeg River above the Seven Portages, conduit lines to the city, a reservoir and pumping station in Winnipeg on the city's property at McPhillips Street, and a filtration plant either in the city or at some point near the Winnipeg River.

19. We estimate the cost of construction of the various projects as follows:

	Cost of First Installation	Ultimate Cost
Red River, filtered and softened.	$2,168.000	$6,870,000
Red River filtered, but not softened . .	2,139,000	6.755,000
Winnipeg River filtered, using wood-stave pipe	3,862,000	10,519,000
Winnipeg River filtered, using steel pipe	6,050,000	17,084,000
Indian Bay, filtered and pumped in the city, using wood-stave pipe.	4,223,000	12,357,000
Indian Bay, filtered and pumped in the city, using steel pipe	8,979,000	26,407,000
Indian Bay, gravity supply, filtered, using steel and wood-stave pipe.	8,218,000	16,601,000
Indian Bay, gravity supply, filtered, using all steel pipe lines	12,634,000	25,627,000
Shoal Lake, not filtered, pumped in the city, using wood-stave pipe	4,585,000	12,667,000
Shoal Lake, not filtered, pumped in the city, using steel pipe	9,180,000	26,419,000

The figures for initial costs cover, in the case of the Red River supply, the outlay for an average daily consumption of 12,000,000 gallons, while those for the Winnipeg River and Shoal Lake supplies cover the outlays for pumping and filter capacities for 12,000,000 gallons daily, and pipe line and reservoir capacities for 17,000,000 and 24,000,000 gallons daily, respectively.

The figures for final costs cover the outlays, in each case, for supplies of 48,000,000 gallons daily.

20. We estimate the annual charges including interest, depreciation, and expenses of operation, to be as follows:

	After First Installation	After Final Installation
Red River, filtered and softened	$359,000	$1,343,000
Red River, filtered but not softened . .	234,000	847,000
Winnipeg River, filtered, using wood-stave pipe	343,000	1,103,000
Winnipeg River, filtered, using steel pipe	468,000	1,474,000
Indian Bay, filtered and pumped in the city, using wood-stave pipe.	338,000	1,098,000
Indian Bay, filtered, using steel pipe	604,000	1,886,000
Indian Bay, gravity supply, filtered, wood-stave and steel pipe lines	506,000	1,108,000
Indian Bay, gravity supply, filtered, using all steel pipe lines.	754,000	1,617,000
Shoal Lake, not filtered, water pumped in the city, wood-stave pipe lines. .	310,000	930,000
Shoal Lake, not filtered, pumped in the city, using steel pipe.	569,000	1,704,000

21. We estimate that the time required to construct the first installation of the works to be as follows: Red River, 2 years; Winnipeg River, 3 years; Shoal Lake, 4 years.

22. Finally, considering the quantity of the water from the various sources, the cost of the works, the time required for construction, and the relative advantages and disadvantages of each project, we recommend that the city go to the Winnipeg River for its future water supply.

The data on which the foregoing recommendations are based will be found in the following pages.

PART I.

Growth of Winnipeg and Water Supply Requirements

POPULATION.

According to official estimates obtained from the Assessors' Office, and given in Table 1, Appendix A, the resident population of the City of Winnipeg has doubled during the past four years, and the present population is now upwards of 111,000 persons. That this estimate is reasonably correct seems probable from the data given in Table 2, showing the number of buildings, the school attendance, the number of sewer connections and water services, and various corroborative data. The substantial nature of this growth is indicated in many ways; for instance, the value of assessable property has trebled in six years; the earnings of the street railway company have trebled in less than six years; the bank clearings have quadrupled; while the post office and inland revenues have correspondingly increased.

The chief reason for this growth is to be traced to the phenomenal development, in recent years, of the Canadian North-West, Winnipeg up to the present time, having been practically the only distributing point for this productive territory. Other distributing centres will probably develop in the future, but Winnipeg is at present the great railroad and commercial centre for this region, and will hold this supremacy, certainly for many years to come.

The manufacturing interests of Winnipeg, while, in individual cases, of considerable magnitude would not, for a city of its size and surroundings, be classed as extensive, but with the prospect of a plentiful supply of good water, there is every reason to believe that certain lines of manufacturing will be developed rapidly, and add much to the wealth and stability of the city.

Estimates of future populations must, of necessity, be based on data more or less uncertain in nature, and, consequently, are likely to prove too high or too low according to individual judgment; nevertheless, in order to plan for the futurewater supply of the city it has been necessary to make such estimates, taking into account, as well as possible, the various modifying local conditions. In order to obtain reasonable bases for these estimates we have interviewed representatives of

the business, the banking and the transportation interests of the city, and have studied the possibilities of the development of the North-West, as well as the growth of various cities in the United States and Canada so situated as to be fairly comparable with Winnipeg. On Plate 1, Figure 2, are shown the populations of various cities, the different curves having been plotted with a view to having them all intersect at a population of 100,000 without regard to the year when that population was reached. The rates of growth of these cities from the time their populations were the same as that of Winnipeg at the present time can thus be readily observed.

It is worthy of notice that the populations of such cities as Chicago, St. Paul and Minneapolis increased rapidly until they reached 200,000 to 350,000, after which the rate of increase diminished for a few years and then again subsequently recovered. This retardation in the rate of growth was due partly to the springing up of new centres of distribution further west, which, for a time, developed at the expense of the larger places; but, with the continued general expansion and prosperity of the whole tributary region their original rates of growth eventually were re-established.

It is quite probable that the growth of Winnipeg will follow a similar course, but the present rate will probably prevail for a number of years. For the purposes of estimate, we have assumed that the rate of increase will diminish gradually rather than suddenly, an assumption which may not represent what may actually happen in the near future, as it is quite possible that the rate may increase instead of diminish, and that the increased rate may continue for some time. It does not seem likely, however, that the present 10% rate of annual increase will be continued permanently. Sooner or later it will drop as low as 4%, the normal average rate of increase for the natural growth of large cities in the west.

The heavy black line drawn upon the diagram in Figure 2, Plate 1, represents, in our judgment, the probable future growth of population of Winnipeg during the next quarter of a century. This line is based on the assumption that during the next five years the rate of annual growth will be 10%, and during successive five year periods, 8%, 6%, 5% and 4% respectively. For a number of years in the immediate future the population may be higher than is indicated by the curve, but eventually it is likely to fall to or even below the curve. It cannot, of course, be claimed that the curve will represent accurately the population at any particular time, but we believe that, eliminating fluctuations in rates of growth, the populations given are sufficiently near the truth to serve as reliable bases for estimates of the required capacities of the water supply works at intermediate periods. According to this curve the population of Winnipeg will reach 250,000 in ten years, and 500,000 in twenty-five years.

In our estimates for a future water supply for Winnipeg we have been instructed to provide for a population of 500,000, which instruc-

tions we have followed for the final installation of the works; but in considering the capacity of the works needed for the immediate future we have been governed by the probable rate of growth of the city, as it would be unnecessary and unwise to build at the present time works large enough for a population of 500,000, on account of the great cost of building and operating works of such magnitude. The estimates, therefore, are based on building, at the present time, works of sufficient capacity to take care of the growth of the city for the next ten or twelve years, and on extending these, as may be necessary, until the final population of 500,000 is reached.

QUANTITY OF WATER REQUIRED.

In 1906, the average daily consumption of water in Winnipeg was 3.18 million gallons, equivalent, if calculated on the basis of the entire population, to about 32 gallons per capita, or if divided among those living in houses which have water connections, to about 35 gallons per capita. At the present time the consumption is in round numbers four million gallons per day.

The average daily water consumption during the past six years has just about kept pace with the growing population; but the number of services having increased more rapidly than the population the amount of water actually supplied per person has decreased, so that to-day it is less than half what it was six years ago.

The maximum and minimum monthly rates in Winnipeg as compared with the average rates have been as follows:

(Million gallons per day.)

Year	Average Rate	Maximum Rate	Minimum Rate	Percentage which Maximum Rate was of Average Rate
1902	1.51	2.11 February	1.01 January	140
1903	1.65	1.96 October	1.27 January	119
1904	2.00	2.72 October	1.46 April	136
1905	2.79	3.32 December	2.21 April-March	119
1906	3.18	3.68 October	2.92 January	116
1907 (Jan.-May)	3.80	4.05 May	3.53 March	—
Average	....	....	....	126

These figures show that the daily average consumption during the highest month has been about 25% more than the daily average for the year.

The excess of the maximum daily consumption over the monthly average is shown by the following figures for the years 1905 and 1906:

Year	Month	Average daily consumption (million gallons daily).	Maximum daily consumption (million gallons daily).	Per cent. which maximum daily consumption was of average daily consumption during the month.
1905	January	2.40	4.75	198
	February	2.64	3.55	135
	March	2.34	3.42	146
	April	2.21	2.72	123
	May	2.21	3.48	158
	June	2.90	4.12	142
	July	3.19	4.32	135
	August	3.12	3.75	120
	September	3.16	4.25	135
	October	2.95	3.57	121
	November	3.04	3.50	115
	December	3.32	3.54	107
	Average	2.79	3.75	136
1906	January	2.92	3.34	115
	February	2.99	3.60	120
	March	2.97	3.68	124
	April	3.04	3.54	116
	May	3.12	3.50	112
	June	3.10	3.52	114
	July	3.51	4.10	117
	August	3.36	4.14	123
	September	3.06	3.98	130
	October	3.25	3.55	109
	November	3.04	3.29	108
	December	3.32	3.98	120
	Average	3.14	3.68	117

The maximum daily consumption is thus seen to have been on an average about 25% above the annual average; but at times it has been as much as 50% to 75% above it. The above figures do not include the water pumped by the "Booster" pump during fires. The data showing the variations in the rate of hourly consumption have been studied in a general way but have not been tabulated.

In estimating the amount of water which should be provided for the future supply of the City of Winnipeg it has been necessary to take into account the population of the city, the per capita consumption, allowances for fire service, and the rate at which the water may be required at given times.

The present water consumption, as indicated by the data furnished by the city engineer, is about 32 gallons per capita daily, figured on the basis of the entire population of the city. The present consumption, however, cannot be taken as an indication of future requirements, for the reasons that the entire population is not now supplied with water, the consumption is largely of a domestic character, comparatively little water is used for manufacturing, and the railroads have supplies of their own. In the future, as the city grows and manufacturing becomes established, the per capita consumption will increase as will also the amount of water required for public uses. Furthermore, the pressure of the water in the city is now far too low for satisfactory service, and with a higher pressure there will be an increase in the quantity of water wasted. The present low rate of consumption is due also in some measure to the hardness and salinity of the water, qualities that render it so unsatisfactory for bathing, and other purposes, that large numbers of householders have private supplies from rain water stored in cisterns and tanks.

A considerable part of the present supply is sold by meter measurement, a practice which is wholly commendable and which should be continued.

We have estimated that, with satisfactory pressure and water of good quality, the present consumption in the city would be at least 60 gallons per capita daily, and that, with the increased growth of the city and the development of manufacturing interests, the per capita consumption will, by 1935, rise to about 85 gallons. This is on the assumption that the meter system is continued in use.

From the estimated population and per capita water consumption we have calculated that in 1910, the earliest date at which new works can be ready for use, the available quantity of water for Winnipeg should be 9,000,000 gallons daily, which amount should increase according to the figures shown in Table No. 2, and also Figure 1, Plate 1, until by 1935 it reaches nearly 50,000,000 gallons.

In providing waterworks for a municipal supply, it is necessary to take into account not only the average daily consumption, but also the variation in draft from day to day and from hour to hour. Furthermore, allowances must be made for fire service, and it must be assumed that fires demanding this service may occur at times when the general consumption is at or near its maximum. Distribution pipes and, in the absence of compensating reservoirs, the main supply pipes must have sufficient capacity to provide for the maximum draft; the same is true of the pumping equipment where the pumping is direct service. Reservoirs must have a capacity large enough to take up the fluctuations in draft, while filters must be built large enough to yield an amount equal to the maximum daily consumption. These various requirements, as applied to Winnipeg, will be set forth at length in connection with each one of the projects which have been studied.

BASIS FOR COMPARISON OF THE VARIOUS PROJECTS.

In order to properly compare the different projects as to their costs of construction and operation, it is necessary to base the calculations on the delivery of certain stated quantities of water into the street mains in the city at a uniform pressure for all the different projects; and further to take into account in each supply the kind and extent of purification required to produce acceptable water, and the sizes and capacities of the component parts of each plant.

Pressure.—It has been assumed that for satisfactory service in the city the water should be delivered into the street mains at a pressure of 70 pounds per square inch.

Quality of Water.—The water supplied to the city should be clear, low in color, free from disagreeable odors or tastes, free from corrosive ingredients, free from excessive amounts of substances forming scale in boilers and, above all, safe and wholesome from a sanitary standpoint.

The qualities of the water from the different sources and the character of the treatment required in each case will be explained in the description of the different supplies.

Capacities of Different Parts of the Works.—In stating the estimates of cost the figures have been given for deliveries of 12,000,000, 24,000,000, 36,000,000, and 48,000,000 gallons of water daily. These amounts do not necessarily represent the capacities for which the works would be built at each instalment, but for the purpose of comparing the relative costs of construction and maintenance of the different projects these intermediate deliveries were chosen to show the variations in cost as the capacities of the plants were increased.

By reference to Table 3, Appendix A, it will be seen that the consumption of water in the city will for several years increase at a greater rate than the population; also that the maximum daily consumption will be, in any year, much greater than the average daily consumption for the year. Further, on certain days the water, for an hour or two, will be drawn from the mains at a rate at least twice as great as the average daily rate per year, and that in addition to this, if a severe conflagration should occur at the time of maximum consumption in the city, the draft from the mains would, occasionally, be at a rate approximately three times the daily average rate for the year.

Although there is now under construction a high pressure fire service system to afford protection in the business part of the city, the existence of these works will not in any way operate to reduce the quantities of water that may be needed in Winnipeg during a large fire in the districts not reached by the pipes of this system. The provision of this high pressure fire service will give great protection to the district in which it is located, particularly to the higher buildings, but its usefulness will be limited strictly to the [illegible]tively small area covered by the high pressure mains, and in maki[illegible] up the estimates of

the quantities of water required for fire protection, therefore, it has been considered that the full customary allowances should be made in each case.

It has been found by experience that in a city of the size of Winnipeg it is unnecessary to provide for the maximum hourly rate in addition to the maximum fire allowance, owing to the short time that the maximum hourly rate prevails. In column 11, Table 8, are given figures which, in our judgment, will provide ample water for all requirements for the periods represented by the average daily consumptions given in column [illegible] of the same table.

These variations in the rate of consumption manifestly govern the design of the different parts of the works. Thus, the high duty pumps which pump the water directly into the street mains, must have, at all times, capacities equal to the maximum rates of consumption; or, to illustrate, for an average daily consumption throughout the year of 22,000,000 gallons, the high duty pumps must be able to supply the water at a rate of 47,000,000 gallons per day.

The basis of the estimates for pumping machinery in the different supplies is given in the following table:

Average Daily Consumption (gallons)	Required effective Pumping Capacity, in gallons, daily	
	Low-lift pumps and pumps at sources of supply	High-lift pumps delivering water into street mains
12,000,000	17,000,000	30,000,000
24,000,000	34,000,000	50,000,000
36,000,000	51,000,000	70,000,000
48,000,000	68,000,000	90,000,000

In the estimates for each installation, given beyond, extra pumping units have been included to make provision for the maintenance of the supply in case a portion of the plant should be, at any time, out of service for repairs or examination.

The effect of the variations in rates of consumption on the sizes of the pipe lines and conduits will be largely governed by the available storage between the conduits and the city distribution system.

Without any storage whatever these conduits and pipe lines would have to be proportioned for the maximum rates of consumption, the same as the high duty pumps above referred to. If storage equal to one day's supply were available, conduits with a capacity equal to the maximum daily rate of consumption would be sufficient.

Clearly the smallest size that could possibly be adopted for the pipe lines, under any conditions, would be such as would deliver the water to the city at the average daily rate of consumption for the year,

but with such conduits it would be necessary to provide so large a reserve to balance the irregularities of draft (which would, at times, exceed the average for many consecutive months) that the arrangements would be far more expensive than the usual one of building the conduits for the maximum daily drafts with reservoirs having a capacity equal to one day's supply; and this latter method is the one which has been used in estimating the costs of the different works.

In Winnipeg there is no opportunity to locate a storage reservoir at a high enough elevation to form a distributing reservoir from which the street mains could be supplied directly at sufficient pressure to give satisfactory service. Hence, either the pipe lines bringing the water to the city must be proportioned for the maximum rate of consumption at all times, including fires, or else the water must be delivered into a reservoir at the ground level and thence be pumped into the mains.

For a gravity supply to Winnipeg, therefore, without pumping, the capacities of the conduits, for different rates of consumption would have to be as follows:

Average daily rate of consumption (gallons).	Conduit capacity required for a gravity supply, without pumping (gallons daily).
9,000,000	25,000,000
14,500,000	35,000,000
22,200,000	47,000,000
30,800,000	60,000,000
39,400,000	74,500,000
49,300,000	90,000,000

Thus, for instance, when the average daily consumption will have reached 49,300,000 gallons, conduits with a capacity of 90,000,000 gallons daily will be required to take care of the maximum rates of consumption and provide a satisfactory excess capacity for fire protection.

For all supplies where the water is delivered into a reservoir in Winnipeg, necessarily at ground level, the sizes of the conduits supplying the water and of the storage reservoirs require adjustment to make an economical plant.

It has been found by experience that if from one-half to one day's supply of water is held in storage, this quantity, when the conduits can deliver the water at the maximum daily rate of consumption, will be sufficient to balance the excess draft due to hourly fluctuations in consumption and provide sufficient reserve for fire purpose.

Interest and Depreciation.—In making up the estimates of the annual costs of operation of the different supplies, interest at the rate of 4½ per cent. per annum has been calculated on the total costs of construction.

No amounts have been included to provide for sinking funds as such, but sufficient sums have been placed under the item "depreciation" to renew the perishable parts of the plants when they wear out, or

have to be replaced, these amounts being assumed to be put out at 3% compound interest to accumulate, in the proper time, the full value of each part, and thus make provision for always keeping the plant in first class condition.

Reservoirs and Conduits—In working out the costs of construction of the different supplies it developed that in each case the most economical plan was that in which the water was delivered to the site of the McPhillips Street pumping station, to be there re-pumped into the street mains, rather than to locate the high duty pumping stations out of town at the intakes or at any considerable distances from the city. All the plans reported upon, therefore, assume the delivery of the water at the present city pumping station, and all take into account the utilization of the present covered reservoir and of such other parts of the works as can be made available.

The suggestion has been made that open channels might be used for conveying the water part of the way from the distant sources, but such an expedient would be more expensive and less satisfactory in every way than the methods proposed herein. Such channels would require concrete linings to prevent their obstruction by vegetation, and to prevent the importation of high color and turbidity; and the cost of such linings would greatly exceed the costs of the pipe lines of equivalent capacities. Furthermore, such channels would require very large sections and considerable depths, on account of the formation of ice, and would be very expensive to maintain in a country where frost goes so deeply into the ground.

The conduit lines might be constructed of wood-stave pipe, steel pipe, cast iron pipe, or reinforced concrete, but after considering these various materials and comparing them on the basis of cost and general suitability to local conditions we concluded that only wood-stave pipe and steel pipe need be considered in the estimates.

In the supplies from Winnipeg River and Shoal Lake, the water of which will be less diffiicult to treat than the ground water or the Red River water, the capacities for coagulating basins and filtered water reservoirs used in the estimates are as follows:

Average Daily Consumption (gallons).	Capacity (in gallons).	
	Coagulating Basins.	Filtered Water Reservoirs.
12,000,000	4,000,000=8 hrs. supply	24,000,000=2 days supply
24,000,000	4,000,000=4 " "	24,000,000=1 " "
36,000,000	8,000,000=5.3 hrs. supply	30,000,000=20 hrs. "
48,000,000	8,000,000=4 hrs. supply	30,000,000=15 " "

The provisions for the storage of relatively large quantities of filtered water in the early years were made as an extra safe-guard in case

extensive repairs might be necessary before the second conduit line was constructed, and this storage, in connection with the water that can be had from the ground water supply when extended, would make a safe supply until the second conduit were in operation.

As several years must elapse before an additional supply of water can be had from a new source, the present system of wells must be extended as rapidly as possible to take care of the growth of the city during this period. It is estimated that in this way provision may be made for a supply of 7,000,000 to 8,000,000 gallons daily. These new works should be of a temporary nature so that at their abandonment, when no longer necessary, the capital expense involved would be as low as possible.

If the ground water supply were developed to the limits mentioned only one conduit line to a new source of supply would be required for the first instalment, for the reason that before this conduit will have been in service ten years the second conduit will have become necessary; while the repairs likely to be required to the first line during these ten years would be of a minor nature, and such as could be made in a comparatively short time, and in all probability without suspending the supply of water. With an ample reserve supply of filtered water, to keep up the domestic and manufacturing consumption, and with the ground water supply to draw upon for fire protection (which it would afford to the extent of about 25 fire streams), the city would not be embarrassed for lack of water during this first period, if depending upon only one pipe line.

On the instalment of the second conduit line connections would be made with the first, with gates and valves so arranged as to enable extensive repairs to be made to the first line, if necessary, without endangering the supply to the city. The ground water supply could then be abandoned, and such parts of the works as might be of service could be incorporated into the new system.

Estimates of cost for the supplies brought from a distance have been made upon the basis of using both wood-stave and riveted steel, in order to show the relative costs of the two types of construction.

Filter Plants.—Filter plants, where required, have been provided with capacities equal to the maximum daily rates of consumption, which are the same as those given in column 5 of the Table 3, Appendix A.

The filters best suited for the purification of the waters of the Red River, Winnipeg River and Shoal Lake are what are generally known as mechanical, or rapid filters, as distinguished from the older type, popularly known as slow sand filters. In both types the fitering medium consists of a bed of sand through which the water is passed, and upon the grains of which the impurities in the raw water are deposited. The designations rapid and slow are descriptive of the main differences between the two types of filters, the rapid filters being operated at a rate such that 100,000,000 gallons of water, or more, can be purified

in a day on each acre of filter surface; while with slow filters from twenty to forty times as much filtering area would be required to purify the same quantity of water in an equal length of time.

In order to secure satisfactory results from rapid filters it is necessary to introduce into the water before filtration an artificial coagulating material which will, by virtue of its stickiness, gather together in relatively large masses the suspended impurities in the water, and prevent them from passing through the sand. The coagulant most commonly employed is a cheap form of alum, commercially known as aluminum sulphate, although lime and sulphate of iron are sometimes used instead. When this substance is placed in water containing the necessary alkalinity, the alum immediately decomposes, and changes to an inert, harmless, insoluble material having none of the characteristics of the original alum.

This inert, harmless substance forms in the water quickly, and is scattered throughout its volume in minute white flakes of a sticky or gelatinous nature, which entangle and cement together the fine particles of clay, silt, organic matter and the organisms present in the water, and as the water passes down through the filters all the suspended impurities are thus caught upon the surface of the sand, where they gradually accumulate until the filters become clogged to such an extent as to necessitate cleaning.

Ordinarily each filter will run for from ten to sixteen hours before cleaning becomes necessary, depending upon the amount of foreign matters in the water, there being times when the runs may be as short as six, or as long as twenty-four hours.

The cleaning of a filter of this type is accomplished by forcing filtered water up through the sand and allowing the dirty water, containing the impurities that had collected in the filters to overflow to the sewer. The washing is continued for from three to six minutes, or until the sand is sufficiently clean, after which the filter is again put in service as before. This method of cleaning does not require the removal of the sand from the filter, nor is there any loss of filtering materials.

The use of alum as a coagulant has a further advantage that it possesses the valuable property of uniting with, and rendering insoluble, the coloring matter dissolved by the water from leaves and decaying vegetation, which, when thus transformed into the insoluble state, will be removed from the water by the filters like any other suspended matter, leaving the filtered water clear, bright and colorless.

Slow sand filters operate at such moderate rates that artificial coagulation is ordinarily not necessary, the suspended matters, including the bacteria, being deposited in the top layers of the sand, practically all within the top three-quarter-inch, and gradually clogging up the surface, as is done more rapidly by the artificial coagulation in the case of the mechanical filters; other actions, which it is not necessary to describe at this point, assist materially in the processes of purification by slov sand filtration. Filters of this type, however, cannot successfully

treat water carrying excessive amounts of finely divided matters, or those colored with vegetable stains, unless a coagulant is used in connection with the process.

The sources of water supply available for Winnipeg are of such character that in each case the system of mechanical filtration is better adapted to their purification than slow sand filtration, and the former, alone, have therefore been provided for in the estimates. The Winnipeg River and Indian Bay waters require decolorization, brought about by the use of chemicals, while the Red River water is too turbid to be economically filtered by sand filtration. Furthermore, mechanical filtration can be easily combined with the process of water softening, which makes it particularly applicable for Red River conditions.

There is no longer any uncertainty regarding the efficiency of properly designed and operated filters of this type.

With respect to the removal of bacteria, their efficiency is as high as that of the slow sand filters, and with respect to the removal of color and turbidity much higher, granting that both types receive intelligent supervision and proper management.

PART II.

Ground Water Supply

PRESENT WORKS.

The City of Winnipeg is supplied with ground water pumped from wells sunk in the limestone rock which underlies the city, all the wells being within the city limits. The principal pumping section is at McPhillips Street, near Logan Avenue, about two miles north-west of the City Hall. There are two other pumping stations located on McPhillip's Street, at distances of one mile and two miles respectively north of the main station. A fourth, located about one mile to the north-west of the main station, is under construction, and others are projected, but their locations have not been chosen.

The city also maintains as a reserve supply the old Assiniboine River works, which formerly furnished the supply to the city, but which were abandoned after the introduction of ground water.

McPhillips Pumping Station (*Wells Nos. 1 and 2*).—When the ground water supply was introduced in October, 1900, the water was derived from an artesian well, known as Well No. 1, 17 ft. in diameter and sunk down 48 feet to rock.

In 1905 a second well, 14 to 15 feet in diameter, and 65 feet deep, and known as Well No. 2, was sunk about 250 feet north of Well No. 1.

Both wells pass through a thick layer of almost impervious clay which extends from a few feet beneath the surface to a depth of about 40 feet. Below the clay there is a bed of coarse gravel, four or five feet deep; and below this, the limestone rock, into which Well No. 2 is driven for sixteen feet. The gravel, which carries more or less water, is probably composed largely of limestone as in the case of the deposits at Bird's Hill. The main supply of water at the well, however, is obtained from the fissures and crevices in the underlying rock.

The well water at this station is softened, and the pumping arrangements are such that either raw well-water or softened water can be pumped to the city.

In order to provide for the hourly fluctuations in consumption, and to have on hand a quantity of water available for fire service, a covered concrete storage reservoir was constructed and put in service in August, 1906. This reservoir which is located about 120 feet west of the boiler house, is 336 feet long, 195 feet wide and 15 feet deep, and

has a capacity of six million gallons. The elevation of high water mark is 765.40 feet.

The pumping equipment at the McPhillips station consists of four pumps—two located in the main pumping station and placed with reference to the use of water from Well No. 1, and two located in the building which covers Well No. 2. The original equipment consisted of:

(*a*). A Worthington steam pump, vertical, duplex, compound, 12x12x20x24, capacity five million gallons, rated maximum pressure 50 lbs., intended for pumping from Well No. 1 to the softening plant, reservoir or street mains. At present it is not in use.

(*b*). A Worthington steam pump, vertical, duplex, triple-expansion, 18, 27 and 50x20x24, capacity five millions gallons, rated maximum pressure 125 lbs., but seldom used above 80 lbs., used for regular city service, pumping from the softening plant or reservoir into the street mains.

In the building which covers Well No. 2 there is a Worthington steam pump, vertical, duplex, triple-expansion, 11, 17 and 30 x 20 x 24, capacity five million gallons, rated maximum pressure 65 lbs. This is the low service pump regularly used to lift water from Well No. 2 to the softening plant or reservoir. In the same building there is also a fire-service pump, called the "Booster," an electrically-driven two-stage turbine pump, having a capacity of five million gallons, and rated maximum pressure is 125 lbs., but seldom used above 80 lbs.

The steam producing equipment at the McPhillip's station consists of five 130 h. p. and two 250 h. p. Babcock and Wilcox boilers. The usual steam pressure is 110 to 115 lbs. Electric power is obtained from a generating plant in the pumping station and a duplicate current from the Winnipeg Electric Railway Company.

The system of supply at this and the other stations is that of direct pumping. The ordinary pressure carried at the pumps is 25 to 35 lbs., but at times of fire it is increased to 80 or 85 pounds. The ordinary pressure in the city is from 20 to 25 lbs.

Pumping Station Well No. 3.—At this station, which was put in service in July, 1906, the general plan of taking the water is the same as in the case of Well No. 2. Well No. 3 is 14 to 15 feet in diameter and about 65 feet deep. The pumping is done with an electrically-driven three-stage turbine pump, having a rated capacity of 2.5 million gallons, and rated maximum pressure of 125 lbs., but the pressure is ordinarily not over 33 lbs., except in case of fire. The pump lifts the unsoftened water from the well and delivers it into the street mains. Power is obtained from the McPhillips station and the Street Railway Company.

Pumping Station, Well No. 4.—This station is arranged similarly to that of Well No. 3. The well is 14 to 15 feet in diameter and about 70 feet deep, and the water is pumped directly into the street mains without softening, the pumping equipment being similar to that of Well No. 3, and of the same capacity.

Well No. 5.—Well No. 5 is not yet completed, but has been sunk to a depth of 80 feet to the rock, and penetrates the latter several feet.

Assiniboine Pumping Station.—The old supply of the city, taken from the Assiniboine River, near the Maryland Bridge, 1.5 miles from the City Hall, is still maintained as an emergency supply in case of fire. This station has not been regularly used since 1905, owing to the pollution of the water, and then only for a short time.

The equipment here consists of two sets of pumps which have a combined capacity of about four million gallons a day. The water passes through an old-style pressure filter, which is in poor order, and almost worthless; it might serve to partially clarify the water, but cannot be depended on to remove disease germs.

This water, which is highly polluted, should never be used except in case of extreme emergency, and if ever so used, a danger warning should be immediately given to the citizens. As soon as possible this station should be abandoned.

CAPACITY OF THE PRESENT WORKS.

The capacity for direct pumping into the mains is as follows:

	Gallons per Day
McPhillips Station and Well No. 2 (Booster)	10,000,000
Well No. 3	2,500,000
Well No. 4	2,500,000
Total	15,000,000

The total available storage capacity consists of the 6,000,000 gallon covered reservoir, the 333,000 gallon basin for softened water and the softening tanks, making a total of about 6,480,000 gallons. There is no storage at Wells No. 3 and No. 4.

Well No. 1 was used from June, 1901, to June, 1905, during which period the maximum monthly average of the daily consumption was 2,720,000 gallons.

Well No. 2 was first used in May, 1905, and from then until June, 1906, furnished the entire supply of the city. During this period the maximum monthly average of daily consumption was 3,320,000 gallons. When Well No. 2 was put in use, Well No. 1 dried up, and since then the water level in Well No. 2 has been kept down by pumping to about the level of the rock.

Well No. 3 was put in service in July, 1906, and Well No. 4 in December of the same year. The largest monthly average of the daily yield has been 580,000 for Well No. 3 and 980,000 for Well No. 4. Since these wells were started up the quantity pumped from Well No. 2 has fallen off, and its yield, with the other two wells running, may be taken as about 2,500,000 gallons per day.

In round numbers the capacities of the present wells when all are in use may be taken approximately as follows:

Well No. 1	0
Well No. 2	2,500,000
Well No. 3	500,000
Well No. 4	1,000,000
Total	4,000,000

Probably larger amounts than these may be drawn for short periods, though not for any considerable lengths of time.

How much additional water will be obtained from Well No. 5, which will be soon ready for service, cannot be foretold, but as it is deeper than the others and is said to tap a large crevice in the rock the yield is likely to be large, especially at first, but extensive pumpage from it will probably reduce to some extent, and possibly to a considerable extent, the yield of the other wells.

The present effective yield of Wells 2, 3 and 4 is only about one-half of what would be required to furnish the present population with an adequate supply of water at good pressure for domestic consumption alone, and when fire service is considered the deficiency is still more marked.

With respect to the distribution system the rapid growth of the city has resulted in over-taxing the capacities of the street mains in many sections of the city, and the system as a whole needs material enlargement to provide for the greater consumption that is sure to follow the introduction of a new supply of better water.

QUALITY OF THE PRESENT WATER SUPPLY.

From a sanitary standpoint, the quality of the present ground water supply of Winnipeg seems to be entirely satisfactory, as indicated by frequent analyses made by the city bacteriologist, which, since June 1st, 1907, have seldom shown more than 10, with an average of not over 3, bacteria per cubic centimeter, and with no organisms indicating fecal contamination appearing in any of the samples examined. There is no reason to believe that the water is at all contaminated.

The artesian water is also satisfactory in its physical qualities, being clear, colorless and odorless, and with a cool and equable temperature. The hardness of the water, and its salinity, give it a marked taste, however, readily detected by one who is not used to the water, but which does not seem to be objected to by those who are familiar with it.

The water is also one of considerable organic purity, and were it not for its objectionable mineral constituents, it would be equal in quality to that of any large city in the country.

Chemically, the water is decidedly unsatisfactory. It is very hard and very saline, properties which make it unpleasant and expensive for domestic use, and unsuitable for use in boilers and many industrial processes. Analyses of the well water, both before and after softening, which have been made from time to time, are presented in Appendix C.

The following is a summary of the most important constituents of the well waters before and after softening, and of the tap water in the city:—

Sample	Mineral Constituents (parts per million).				
	Chlorine	Hardness	Alkalinity	Incrustants	Magnesium
Wells No. 1 and 2, unsoftened	245	480	360	120	63
Well No. 2 softened. . .	245	210	90	120	34
Well No. 3	202	465	348	117	59
Well No. 4	222	475	342	133	59
Tap water (calculated mixture	222	307	185	122	42
Tap water, 1906, (by analysis)	. . .	304	186	118	. .

It will be seen from these figures that the well water at the McPhillips station before softening had a hardness of 480 and after softening 210. The softening process used at present does not reduce incrustants or permanent hardness, but only the alkalinity, or temporary hardness. This was reduced from 360 to 90, a result which may be considered as reasonably satisfactory, although some of the best softening plants in use effect a somewhat greater reduction than this.

Before the use of water from Wells Nos. 3 and 4, all the water pumped was softened, and the figures given for the softened water represented the supply of the city. Some analyses made during 1905 showed that the tap water had an average hardness of 188 parts per million, and that the alkalinity averaged 80, occasionally, however, running down as low as 58.

The water now furnished to the city is a mixture of the softened water from Well No. 2 and unsoftened water from Wells Nos. 3 and 4 in the proportion of about 2.5 million gallons of softened water to 1.5 million gallons of the untreated water.

The chlorine, present in the ground water, cannot be removed by any known practicable process, and this is one of the most objectionable features of the present supply.

The amount of iron in the water is comparatively low, but occasionally there is noticed in the tap water a slight roiliness due to iron-

rust, a phenomenon in which the pipes are as much concerned as the water. Rust deposits are sometimes noticed in the porcelain bowls under the hot water faucets, which is a common occurrence in waters which contain large amounts of carbonic acid. Trouble from this source, however, does not appear to be serious.

WATER SOFTENING PLANT.

The water softening plant was recommended by Mr. Rudolph Hering in 1897. It was built by the Pittsburgh Testing Laboratory, Ltd., and put in operation in July, 1901. This gave to Winnipeg the distinction of being the first large city on the American continent to establish a municipal water softening plant.

The process consists of the treatment of the water with lime, followed by a precipitation of the sludge in tanks, filtration through cloth filter-presses, and subsequent carbonation of the effluent with the products of combustion of burning coke. A complete description of the plant was published by Mr. James O. Handy, in the Engineering News of May 26th, 1904, to which reference is made for details of construction.

The softening process is limited to the removal of the carbonates of lime and magnesia and no attempt is made to remove the sulphates. The analyses which have been made indicate that the efficiency of the plant has been reasonably satisfactory in accomplishing the work for which it was designed, though it has not by any means completely softened the water.

The efficiency of the plant in removing the hardness is shown by the figures given in Table No. 5, Appendix C. They indicate that the total hardness is reduced by about 56 per cent. and the temporary by 75 per cent., while the permanent hardness and the chlorine remain unchanged. The magnesium is reduced by about 46 per cent. The well water contains but little iron, all of which is removed during the softening process, and between 20 and 30 parts per million of free carbonic acid; but analyses are not at hand to show the amount of carbonic acid left in the water after treatment. Without the use of the coke burning apparatus the water would be free from carbonic acid and would have a slight alkalinity due to the presence of normal carbonates. With the coke burning process in use, regulated to supply just the right amount of carbonic acid, these normal carbonates would be changed to soluble bicarbonates with no excess of carbonic acid; but if not properly operated there may be supplied to the water an excess of carbonic acid fully as large as that present in the well water before treatment.

The softening plant has a guaranteed capacity of 2,400,000 gallons per day, which is a little less than is customarily pumped from Well No. 2.

The figures given in the following table show the average quantities of chemicals used in the softening process:

Year	Quantity of Water Softened (million gallons daily)	Average Quantities of Chemicals Used					
		Pounds per Day			Pounds per Million Gallons		
		Lime	Coke	Acid	Lime	Coke	Acid
1903	1.54	5219	875	45	3390	569	29.2
1904	1.79	5686	894	61	3180	498	34.1
1905	2.19	7223	755	67	3300	345	30.6
1906	2.36	7797	620	65	3300	263	27.5
1907 (5 months)	2.33	8067	555	61	3465	237	26.2
Average					3327	382	29.3

During the last five years there has been required an average of 3327 lbs. of lime per million gallons of water for softening, 382 lbs. of coke for changing the normal carbonates to bicarbonates and 29.3 lbs. of acid for cleaning the cloths used in the filter presses.

The cost of these chemicals has been as follows:—

Lime—3327 lbs. at 0.63c	$20.95
Coke—382 lbs. at 0.15c	1.91
Acid—29.3 lbs. at 1.5c	0.44
	$23.30

From these figures it will be seen that the cost of chemicals has been about $23 per million gallons.

The softening plant does not now appear to be in first-class physical condition, although it is operated in a fairly satisfactory manner, and gives as good results as could reasonably be expected. The least satisfactory part of the plant appears to be the apparatus for adding carbonic acid to the water after it passes through the filter presses, which does not admit of being so regulated as to supply the amounts of carbonic acid needed at different times in just the right proportions.

EXTENSION OF GROUND WATER SUPPLY.

The City of Winnipeg is located in the basin of an ancient glacial lake, known as Lake Agassiz. This lake extended as far south as the head waters of the Red River, and as far north as the Nelson River, including Rainy Lake and Lake of the Woods on the east side, Lake Manitoba and Lake Winnipeg on the north, and extending to the Pembina Mountains on the south-west.

The floor of the lake is largely granite, but in the basin there have been gradually deposited various layers of sand, clay, limestone, shale, etc. The outlines of the lake are distinctly shown by the sand and gravel beaches, which are especially conspicuous along the south-west border, where they offer a marked contrast to the general prairie surface.

Beneath the City of Winnipeg there is a deposit of sedimentary clay, varying in thickness from 40 feet to 60 feet and interspersed with strata of sand and gravel, some of which are water-bearing and contain, in all probability, a rather high percentage of limestone. Below the gravel lies the limestone rock.

Test wells have been driven by the city, by the railroad companies and by others, for the purpose of exploring the underground water supply. Some of these wells have given fairly good flows, while others have yielded but little or failed entirely. Failure or success appears to have been largely a matter of chance and has depended upon whether or not the well happened to strike one of the crevices in the limestone formation. Notwithstanding all the work that has been done, no adequate survey has been made of the underground waters and time has not permitted us to carry on an extensive investigation along this line. In passing judgment upon the question of the probable quantity of water available from this source, we have, therefore, been compelled to rely more upon general experience than upon the local data available at Winnipeg.

QUALITY OF THE GROUND WATER.

The quality of the ground water which furnishes the present public supply of the City of Winnipeg has been already referred to and has been characterized as very hard and very saline. All of the ground water within the city limits, as shown by the analysis of various wells, is substantially the same in character as that of the public supply, although some have shown slight differences in hardness, dependent upon their depth and upon the character of the strata through which they pass. Generally speaking the wells near the river are more saline and contain more permanent hardness but less temporary hardness than those further away.

So far as can be learned from the data at hand, the character of the ground water north of Winnipeg does not change materially for ten or twelve miles. North of that, however, the water is somewhat less mineralized. At Poplar Springs, which is about 17.5 miles from the city, the water is somewhat softer and contains much less chlorine than the local water. For example, the ground water underlying the City of Winnipeg contains about 250 parts per million of chlorine, whereas the water at Poplar Springs does not contain more than 15 to 35 parts per million. At Stonewall, about 5 miles south-west of Poplar Springs, the chlorine is also relatively low; so also at West Selkirk, East Selkirk

and St. Clements. As nearly as can be ascertained, the dividing line between the water which is high in chlorine and that which is low is ten or twelve miles north of the city. South-west of the city the chlorine in the ground water is high, and particularly so in deep wells.

While there has been a good deal of speculation as to the origin of the ground water underlying Winnipeg, it is, perhaps, hardly worth while to go further into the question, for the reason that the quality of the water is such as to make it unsatisfactory as a source of public water supply. It has been already stated that while the hardness can be removed to a satisfactory degree, chlorine cannot be removed by any practicable process, and is very objectionable when present to the extent of 250 parts per million, the amount in the present supply of the city.

In order to obtain a good ground water for the city it would be necessary to go a distance of ten or twelve miles north and drive there a series of wells or collecting galleries and conduct the water to some central point where it could be softened and pumped to the city. The water thus softened would be practically equal in quality with the Red River water after softening and filtration.

QUANTITY OF GROUND WATER.

We have not been able to ascertain with any degree of certainty from the facts at hand the quantity of water which can be secured from the ground. The data cannot be obtained without an expenditure of time and money which we do not feel is warranted, considering the quality of the water.

The average rainfall in the vicinity of Winnipeg may be taken as about 18 inches per year, a large part of which falls in the summer, when the days are long, the temperature high, the air dry, and the evaporation large. For a supply of forty-eight million gallons daily there would be required a gathering ground of nearly a thousand square miles.

The general movement of the ground water in this region is naturally towards the rivers and could be intercepted by a series of wells or collecting galleries located at right angles to the line of flow. We believe that the amount of water continuously obtainable by such a series of wells would not exceed one million gallons per lineal mile of conduit, and that the wells, if located nearer together than about two miles, would each affect the yield of the others next in proximity. It seems probable that each station so located might be depended upon to yield a million gallons of water daily, and we have used this as a basis in making up the estimates of the cost of extending the present ground water supply.

On account of the quality of the water and its very uncertain quantity, we do not consider this source of supply as one to be recommended under any circumstances. But, to enable a comparison to be made of this with other plans considered, we have included an approxi-

mate estimate of the cost of development of a ground water supply. The following is a summary of these estimates:—

For an Average Daily Supply of	Cost of Construction	Annual Cost of Operation and Maintenance
12,000,000 gallons	$2,800,000	$ 485,000.00
24,000,000 gallons	5,000,000	945,000.00
36,000,000 gallons	7,500,000	1,400,000.00
48,000,000 gallons	9,700,000	1,870,000.00

PART III.

Red River Supply

The Red River of the north rises in Lake Traverse, in the United States, about 400 miles south of the Canadian boundary. It flows in a northerly direction between the States of Minnesota and North Dakota, and thence onward to Lake Winnipeg. Its total length is approximately 550 miles. Its drainage area above the City of Winnipeg, the greater part of which consists of prairie land, as about 46,200 square miles, of which about 39,500 are in the United States and 6,700 are in Canada. The river bed is a more or less uniformly deep cut in the broad valley, and the bottom is about 20 to 40 feet below the prairie level. The river is navigable from Grand Forks to Winnipeg, and is used by flat boats and scows for carrying grain and other produce.

The flow of the river is sluggish, as the slope of the prairie rarely exceeds one foot, and, for a considerable part of the distance, is not more than six inches to the mile.

The discharge of the stream was measured at Grand Forks, above which point the drainage area was 25,800 square miles, by the United States Geological Survey, from April to November, 1905. During this period the maximum discharge was 16,700 cubic feet per second and the minimum discharge 1,900 cubic feet per second, both extremes occurring during the month of May. The ordinary low flow, according to these observations, is probably about 0.07 cubic feet per second per square mile. At this rate the flow of the river above the City of Winnipeg would be about 3,200 cubic feet per second, or something over 2,000 million gallons per day. Inasmuch as the rainfall is lower over the northern part of the watershed than over the southern part, and as the evaporation in the prairie region is large, the minimum flow of the river at Winnipeg is probably less than this figure, possibly not over 1,000 million gallons per day.

POPULATION ON THE WATERSHED

According to the figures given in the United States census of 1900 and the Canadian census of 1901, the total population on the Red River watershed above Winnipeg was 445,600, or about 10 per square

mile, of which only 0.6 per square mile were in cities having a population of 4,000 or more. Since these censuses were taken the population throughout the valley has increased considerably, so that at the present time the total population may be estimated as about 15, and the urban population as 1 per square mile. The principal cities on the drainage area are Fargo and Grand Forks, in North Dakota, and Crookston and Fergus Falls, in Minnesota. Considering the size of the drainage area and the flow of the stream, the pollution derived from these centres of population is extremely small. It will unquestionably increase during the next generation, but even with an ample allowance for such increase, the relative amount of pollution will be very low when compared with many rivers of the United States which are used for public water supplies. In order that a comparison may be had between the Red River and other rivers used for water supplies on the basis of stream pollution, the following figures are given:—

Place	Water from what river	Urban Population per square mile
Philadelphia	Delaware, Schylkill	128
Albany	Hudson	59
Pittsburgh	Allegheny, Monongahela	37
Indianapolis	White	36
Louisville	Ohio	25
Paterson	Passaic	22
Toledo	Naumee	17
Allegheny	Allegheny	16
New Orleans	Mississippi	7
Washington	Potomac	7
St. Louis	Mississippi	6
Kansas City	Missouri	2
St. Joseph	Missouri	1
Minneapolis	Mississippi	1
Winnipeg	Red River (proposed)	1

The Red River is subject to one source of pollution which most rivers do not receive, namely, deposits of manure from farm lands adjoining the stream. The prairie land is now used largely for cultivation of wheat, and the fertility is so great that manure, instead of being spread upon the land, is thrown away, and the most convenient place for the farmers to dispose of it is upon the shore of the stream, or upon the ice in the winter, where the current can carry it off. Such pollution is unlikely to give rise to typhoid fever among those using the river water, but it is undoubtedly objectionable. The practice of dumping the manure into the stream may not be discontinued for many years, but will ultimately stop when the farmers realize that the constant taking of crops from the soil without restoring its fertility is unwise and unprofitable.

QUALITY OF THE WATER.

The Red River water for a large part of the year is comparatively free of turbidity, but in the spring, after the ice has disappeared, very high turbidities may prevail for several weeks, and sometimes for several months. Observations of the turbidity of the Red and Assiniboine Rivers have been made at Winnipeg for the last three years, the observations having been made daily during the turbid periods, but at other times less frequently.

During the winter, when the stream is covered with ice, the water has a turbidity probably averaging not far from 5 on the silica scale; during the late summer the turbidity sometimes rises above 50 and would probably average about 25; while during the months of April, May and June it varies considerably, according to the season. During 1905, when daily observations were carried on for three months, the turbidity showed two periods of marked rise, one, in April, when it suddenly rose to 750 and then gradually dropped to about 150, and the other during May, when it increased to 1,000 and then dropped back to about 200 to remain at this figure through June. In the spring of 1907 the turbidity reached 3,600, remaining for a whole month higher than 1,500 and gradually falling to about 200 during May and June. The turbidity observations of the Red River do not differ very markedly from those in the Assiniboine, although such differences as are noted have shown that the Red River is the more turbid stream of the two. The increase in turbidity after a rain seems to occur somewhat earlier in the Assiniboine than in the Red River.

The color of the Red River water is comparatively low. Few color observations have been made, but thus far the maximum observed has been 60, and the average for the year may be taken as about 20 on the platinum scale.

The Red River water, on account of the organic matter and clay carried in suspension, has naturally a slight vegetable and earthy odor, and also a "hard" taste, due to its mineral constituents. The particles of clay and silt, which cause the turbidity, seem to be of large size when compared with the water of many streams in the United States, for on standing they settle out with comparative rapidity. Enough fine particles are present, however, to render the water distinctly turbid even after settling for twenty-four hours.

The few bacteriological analyses of the Red River water which have been made show that the water is contaminated, all the samples tested during 1906-7 showing the presence of the colon bacillus. The numbers of bacteria ranged from about 1,500 to nearly 3,000 per c. c., but most of the analyses were made at times when the river was in flood, and when the turbidity of the water was high. In all probability, the numbers of bacteria are very much lower during the winter, when the water is frozen, and also during the summer and fall.

The Red River water is not as hard as the water at present supplied to Winnipeg, and is not quite as hard as the water in the Assiniboine River, but yet it must be classed as a very hard water. From the dozen or more analyses which have been made during the past two years the total hardness of the water under average conditions may be taken as about 250 parts per million, although, at different times in the year, it varies from 150 to 350. When the stream is in flood the hardness of the water is at its lowest point, while during low water, when it receives relatively larger accessions of the hard ground water, the hardness of the river water increases. Of the 250 parts per million of total hardness, about 180 may be taken as representing the alkalinity, or temporary hardness, and about 70 as incrustants, or permanent hardness. The alkalinity of the water varies at times from 120 to 250 parts per million, and the incrustants from 30 to 100.

Analyses of the water at Grand Forks, N.D., showed about 5 parts per million of chlorine, which is about the minimum figure observed at Winnipeg during times of flood. In periods of low water, however, the chlorine at Winnipeg increases, at times going as high as 75 parts per million. The average amount of chlorine in the water of Red River may be taken as about 20 parts per million, which is approximately one-twelfth of what it is in the present well water supply of the city.

For the sake of comparison, the average hardness of the water in the Assiniboine River may be taken as 375 parts per million, with variations from 200 to 500, and the alkalinity averages about 250, varying at different times from 100 to 350; the incrustants average about 125, and vary from 100 to 150. The chlorine averages about 30 and varies from 10 to 50.

PURIFICATION REQUIRED.

The Red River water in its natural condition is not suitable for use as a public supply, partly on account of its turbidity, partly on account of its unsanitary quality, and partly on account of its high hardness. With proper treatment, it can be made suitable for use, but not without the use of chemicals. Plain sedimentation, or plain sedimentation and sand filtration would not be satisfactory, nor would sedimentation with the use of chemicals suffice; it is necessary to resort to what is called mechanical filtration, which combines the use of a coagulant with rapid filtration through sand, as has been already described.

The water can be purified and rendered safe and wholesome, clear and colorless without softening, but inasmuch as chemicals are required in any case, it would be much better to soften the water as well as clarify it. In deference to the request of the Committee we have estimated the cost of this water both with and without softening, but as we find that the water unsoftened would not be satisfactory for a public supply, we advise the estimate based on the use of unsoftened water be left out of consideration.

LOCATION OF PURIFICATION WORKS.

If the Red River water is to be used, the location of the intake must be at a considerable distance from the city in order to avoid danger of local pollution in the future. One point which we have considered is on the west side of the river at St. Vital. This locality is eight miles from the mouth of the Assiniboine River along the course of the stream, but it is 4.75 miles in a straight line from the City Hall, and only 1.3 miles beyond the present limits of the city. Whether or not this point would be sufficiently far away from the city to avoid danger of local contamination will depend upon whether or not the city grows in that direction beyond this point. The present area of the city is now 13,999 acres. The density of population in the different wards is as follows:

Ward No. 1	2.2	persons per acre
" " 2	24.7	" " "
" " 3	7.5	" " "
" " 4	22.5	" " "
" " 5	11.4	" " "
" " 6	7.4	" " "
" " 7	3.3	" " "
Entire city	8.0	" " "

If we look forward to a population of 500,000, the density of population over the whole city would be 36 per acre unless the present city limits were extended. Judging from the history of the large cities of the United States, these present city limits will undoubtedly be extended. The following figures show the density of population in several United States cities, for purposes of comparison:

City.	Population per acre.
Chicago	14
Minneapolis	6
St. Paul	5
Detroit	16
Cleveland	17
Toledo	8
St. Louis	15
New York	16

The population density in Winnipeg will not be likely to exceed 16 per acre, as there are no natural limits to expansion. For a population of 500,000 there would be needed on this basis 33,333 acres, that is. the city would cover nearly two and a half times its present area when that population is reached. If the city should grow equally in all directions it seems more than likely that before a population of 500,000

were reached the city limits would be well beyond St. Vital. The region at the south is rapidly growing up as a residential district, and already the water mains of the city extend to a point less than a mile and a half from St. Vital. It is not improbable that the river in this section may be ultimately bordered with manufacturing establishments.

In view of these facts, we feel that it would not be safe to locate permanent works at St. Vital, but that it would be wiser to place them at some point near St. Norbert. The location which we show on the map is merely a tentative one, and could be moved up or down the river a mile or two, should it be found desirable for any reason to do so. The proposed location of the works at St. Norbert is eight miles from the City Hall, in a direct line, and fourteen miles by the river.

LAND REQUIRED.

The original installation would require about ten acres of land, but it would probably be wise to acquire a tract of twenty or more acres.

GENERAL LAYOUT.

The general layout of the purification works would be as follows: Water would be pumped from an intake in the river by centrifugal pumps to settling basins on the shore. Before the water entered the settling basins it would receive a dose of lime and soda, or in case it were not to be softened, a dose of alum. These settling basins would have a combined capacity of about one day's average consumption; they would be covered and well baffled to facilitate coagulation and sedimentation. From the settling basins the water would flow by gravity to coagulation basins of small capacity adjacent to the filters, where it would receive, if necessary, a supplementary dose of alum in order to properly prepare the water for filtration.

Passing from the coagulation basins to the filter house, the water would flow through a series of filter beds, each capable of filtering at the rate of 1.5 million gallons per day. This filtration wolud be a rapid rate, say one hundred million imperial gallons per acre per day, which is more than twenty times as much as is generally used in case of sand filtration. When the sand of the filters becomes dirty, it would be washed by an upward current of water aided by compressed air, the dirty water being allowed to flow out through sewers into the river. From the filters, the water would pass to a pump well and be pumped by centrifugal pumps from thence to a pure water reservoir at McPhillips Street, where high duty pumps would send it into the city mains.

The filters would be enclosed in a building which would serve for the general purposes of a filter house and also contain devices for apply-

ing and controlling the chemicals and a laboratory for testing the efficiency of the process at frequent intervals.

CHEMICAL TREATMENT.

If the Red River water is to be clarified but not softened, two methods of treatment are available, namely, the use of alum as a coagulant, or the use of sulphate of iron and lime in combination.

The data showing the turbidity of the water at different seasons are not very complete, but from the best information available we have estimated that for five months in the year the turbidity of the water, after passing through the settling basin would be about 5; for five months it would be 20, and for the remaining two months 250. The amount of chemicals required to clarify the water depends upon the amount of the turbidity. We have estimated that, if the alum treatment were adopted, 150 lbs. per million imperial gallons per day would be required; and assuming a cost of 1.7c. per lb. delivered at the filters, this would make the cost of chemicals $2.55 per million gallons.

If lime and iron were used, we assume there would be required 225 lbs. of ferrous sulphate, that is, copperas, per million gallons and 160 lbs. of 90% lime. At an assumed cost of 1c per lb. for copperas and 0.65c per lb. for the lime, the cost of chemicals with this method would be $3.40, which is $0.85 more than in the case of the alum process. Alum is easier to manipulate than lime and iron, and as it is cheaper in this case, it would be preferable to use it.

To soften the water, and at the same time to clarify it, would require the use of both lime and soda. At times of excessive turbidity, say for a few weeks in the spring of each year, it might be necessary to use a small amount of iron or alum. For the softening alone, we have estimated that there would be required 2,100 lbs. per million gallons of 90% lime and 760 lbs. per million gallons of soda-ash. At an assumed cost of 1.7c per lb. for soda-ash, and 0.65c per lb. for lime, the cost of chemicals for softening the water would amount to about $26.50 per millon gallons. To this, it might be necessary to add for the alum or iron required in the spring, a cost of about $1.25.

It would be possible to use lime and iron in such a way as to clarify the water and partially soften it. This would be the same process as the one above mentioned, except that more lime would be used. The temporary hardness would be reduced about the same as it now is in the case of the softening plant at McPhillips Street. The sulphates would not be reduced unless soda were used in addition, which would make the process practically the same as the regular softening process above mentioned. The cost of this half-way treatment would be about $10.50 per million gallons. Such a half-way method would not prove satisfactory to the people of Winnipeg, as it would still leave in the water a large amount of permanent hardness, which is most objectionable from the standpoint of boiler use.

RESULTS TO BE EXPECTED FROM FILTRATION AND SOFTENING.

Although the Red River water is unfit for use in its present condition, it can be made suitable by the adoption of a proper treatment. The turbidity and the color can be almost wholly removed, and the filtered water can be made practically as clear and colorless as the water at present supplied to the city. The hardness of the water can be reduced from 250 to about 75 parts per million gallons, of which about 60 parts are temporary hardness and about 15 parts permanent hardness. The chlorine cannot be altered, but, as it is seldom very high, we do not anticipate that this would be the cause of any serious trouble in the use of the water. By the use of proper methods of purification and softening, the Red River water can be made palatable, attractive in appearance, safe and wholesome from a sanitary standpoint, and satisfactory for boiler use and for general manufacturing purposes.

COST OF BUILDING AND OPERATING THE WORKS.

The estimates of cost of construction and operation have been made upon the basis of filtering and softening the water, as well as upon filtering only, without softening. Summaries of these estimates follow, the itemized estimates being given in Appendix D:—

SUPPLY FROM RED RIVER.

Summary of Estimates of Cost of Construction and Annual Cost of Operation and Maintenance.

Red River Water, Filtered and Softened.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000.	$2,168,000.00	$ 359,000.00
24,000,000.	3,458,000.00	671,000.00
36,000,000.	5,413,000.00	1,018,000.00
48,000,000.	6,870,000.00	1,343,000.00

Red River Water, Filtered, but not Softened.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000.	$2,139,000.00	$ 234,000.00
24,000,000.	3,400,000.00	423,000.00
36,000,000.	5,327,000.00	646,000.00
48,000,000.	6,755,000.00	847,000.00

PART IV.

Winnipeg River Supply

The watershed of the Winnipeg River above Lac du Bois, twenty-six miles above the proposed intake, covers approximately 57,000 square miles, and, with the exception of a small portion in Manitoba and a somewhat greater area extending down into the United States, lies largely in the Province of Ontario. Within the watershed are the Lake of the Woods, Rainy Lakes, and the English and Winnipeg Rivers, with their various tributaries.

The rocks underlying the surface of the watershed are largely laurentian, consisting of granites, schists, trap, quartzites, and other igneous rocks. The watershed is covered with lakes, and is extensively timbered. Comparatively large swamp and muskeg areas lie adjacent to several of the lakes and along the courses of some of the streams.

The course of the Winnipeg River, between the outlet of the Lake of the Woods and the point chosen for the location of the intake, is marked by several waterfalls and rapids, the total descent amounting to about 163 feet in a distance of approximately one hundred miles. Usually the rapids or falls are separated from each other by stretches of from one to six miles of comparatively quiet water.

The minimum flow of the river is said to be about 17,000 cubic feet per second at Lac du Bois, which corresponds to a flow of 0.3 cubic feet per second per square mile, but that, on account of the diversion of water through the Pinewa River, the available flow at the point of intake cannot be depended upon to be more than 9,000 cubic feet per second, or 4,800,000,000 gallons per day.

The water of Winnipeg River, flowing from a watershed of the character described, is naturaly soft. It is, however, somewhat, though not highly, colored with organic matter, acquired from the swamps and muskegs, and has a slightly vegetable taste.

The water is usually fairly clear, the turbidity ranging from five to fifty parts, and averaging probably not over about ten parts per million. The chlorine is also very low—so low, in fact, as to be entirely negligible.

The only considerable population upon the watershed at present from which contamination might arise, is at Kenora and the adjacent

villages located near the outlet of the Lake of the Woods; and while this, at the present time, could not be considered a serious menace, the conditions will undoubtedy become much worse, as the population increases, and, taken in connection with the color, turbidity, and presence of vegetable organisms which have been carried out into the river from the lakes and swamps, point to the necessity of filtration to render the water acceptable for a public supply for Winnipeg. The Winnipeg River water, however, would be easy to treat and when purified would very closely approach the requirements of an idea municipal supply.

DESCRIPTION OF THE WORK REQUIRED.

At the point chosen for the location of the intake, which would be placed above the Seven Portages, there is little likelihood of any trouble from the formation of frazil or anchor ice, and such likelihood as might exist may be entirely removed by the erection of a low dam, about eight feet high, across the river, or by some other device. This dam would provide slack water for a distance of at least seven miles up stream from the intake. It is proposed to build the intake and gatehouse for a capacity of 48,000,000 gallons daily and to provide a pumping station equipped with high duty steam pumps to force the water over the height-of-land lying west of Whitemouth River, with conduit lines leading thence, to Winnipeg, to a coagulating basin, from which, after subsidence and coagulation, the water would pass through rapid filters to a filtered water reservoir, and this would be pumped by high duty pumps, having a capacity equal to the maximum rates of consumption, directly into the street mains. An alternative arrangement of the works would be to place the filters nearer the Winnipeg River. The cost of construction would not be materially different, however, from the arrangement assumed.

The water would be brought from the Winnipeg River to the City of Winnipeg in three separate pipe lines, one of which would be built immediately, the second when the average daily consumption of water in the city would have reached about 17,000,000 gallons, and the third when the average consumption shall have reached 33,000,000 gallons daily. Each conduit would have a carrying capacity of 23,000,000 gallons daily.

Each pipe line would be made up of three sections, the first extending from the Winnipeg River to the height-of-land west of the Whitemouth River, a distance of 38,500 feet; the second, from the height-of-land above mentioned to a point 26,400 feet west, across the elevated plain in which the Julius muskeg is situated; the third, reaching from the edge of this plain to the City of Winnipeg, a distance of 229,700 feet. For purposes of estimate, owing to the different slopes available for the pipe lines in these three sections, the sizes of the pipes have been varied correspondingly, as follows, though in actual construction a somewhat different arrangement might be found advisable:

Section	Length	Diameter of Pipes if of wood staves	Diameter of Pipes if of riveted steel
First	38,500 feet	45 inches	50 inches
Second	26,400 feet	54 inches	60 inches
Third......	229,700 feet	48 inches	53 inches

The coagulating basin in Winnipeg, into which the water would be discharged from the conduit lines, would be built in two instalments, the first having a capacity of 4,000,000 gallons and the second, to be built when the consumption of water in the city shall have reached 24,000,000 gallons daily, to have a capacity of 4,000,000 gallons additional, making a total of 8,000,000 gallons, which would be large enough to take care of the growth of the city until the average water consumption shall have reached 48,000,000 gallons daily.

The filters would be built with capacities corresponding to the maximum daily consumption of water and would be extended, from time to time, as necessary, the cost of adding new units being in about the same proportion, per million gallons of capacity, as the original installation.

The filtered water reservoir with a capacity of 18,000,000 gallons in addition to the present storage capacity of 6,000,000 gallons, would be ample in size until it became necessary to build the third pipe line, when a further extension of about 6,000,000 gallons would provide ample reserve until the average daily water consumption shall have reached 48,000,000 gallons.

The pumping stations, at the Winnipeg River and in Winnipeg City, the filters, and filtered water reservoirs, would be built of capacities conforming to the requirements as stated in Part I.

The country, with the exception of about five miles across the high lands west of the Whitemouth River, being favorable for construction, no unusual difficulties, other than those incident to the delivery of materials, and the construction of the work in the muskeg country, are to be expected in the five miles above referred to.

With the exception of a few miles at the upper end of the line the work will be accessible to the railroads and it is proposed, and taken into account in the estimates, to construct a train line from Whitemouth Station to the site of the pumping station on the Winnipeg River, to be used for the delivery of the heavy parts of the pumping engine during construction, and for supplies and fuel during the operation of the works.

In reaching the decision as to the best manner of developing the Winnipeg River supply, many studies were made to determine the effect upon the cost, and upon the times when additions to the plant would become necessary, of dividing the pipe line into different capacities; of providing larger storage for filtered water, thus reducing the sizes of the pipe lines; of putting a storage reservoir on the height-of-

land west of the Whitemouth, and of placing the filters at the source of supply rather than in the city; and of all these the plan here presented is the least expensive and most satisfactory, when considered in connection with the minimum outlay in the immediate future and security against interruptions of the supply.

The estimate of the cost of pumping at the Winnipeg River pumping station is based on the installation of high duty crank-and-fly-wheel steam pumps. It would be possible, however, to install an electrical pumping plant with auxiliary steam pumping machinery of a less expensive nature than that considered in the estimates.

The operation of this plant will present no difficulties either in the matter of pumping or purification. With the tram line for the delivery of fuel, the telephone line between the city and Winnipeg River pumping station, and with pumping machinery provided with spare units, there should be no greater difficulty in operating this station than the one in the city.

The process of filtration will be simple, as but one chemical, aluminum sulphate, would be required.

In the estimates of cost of construction and operation the foregoing conditions have been taken into consideration. The detailed estimates of cost of construction and operation will be found in Appendix D, summaries only being here presented for convenience.

SUPPLY FROM WINNIPEG RIVER.

Summary of Estimates of Cost of Construction and Annual Cost of Operation and Maintenance.

With Wood-Stave Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Cost of Operation
12,000,000........	$3,862,000.00	$ 343,000.00
24,000,000........	6,538,000.00	620,000.00
36,000,000........	9,593,000.00	922,000.00
48,000,000........	10,519,000.00	1,103,000.00

With Steel Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Cost of Operation
12,000,000........	$6,050,000.00	$ 468,000.00
24,000,000........	10,915,000.00	870,000.00
36,000,000........	16,159,000.00	1,292,000.00
48,000,000........	17,084,000.00	1,474,000.00

PART V.

Shoal Lake Supply

The Lake of the Woods is situated about one hundred miles east of Winnipeg, and lies chiefly in the Province of Ontario, but partly also in Manitoba and the United States. It has a drainage area of about 27,700 square miles, a water surface of about 1,500 square miles, and is studded with islands. The principal inflowing stream is Rainy River which enters from the south with a drainage area of about 9,700 square miles.

Shoal Lake, in the north-west angle of the Lake of the Woods, has a drainage area of about 360 square miles, with a water surface of 107 square miles, and is connected with the main lake at Ash Rapids. At the north-western corner of Shoal Lake there are [illegible] large bays separated from the main body of the Lake by narrow channels, and known as Indian Bay and Snowshoe Bay. Indian Bay Narrows is about two miles long and approximately a quarter of a mile wide. Above the Narrows the water surface of Indian Bay has an area of about 8.5 square miles, with a length of about six and a width of three miles. The average depth is probably less than twenty feet and probably not over fifteen feet, the total storage capacity being approximately twenty-two billion gallons, or about 1.5 billion gallons per foot of depth.

Falcon River, the principal tributary stream of Shoal Lake, flows into Indian Bay at its westerly end, and has a drainage area of 72 square miles, which includes Falcon Lake and High Lake besides several smaller bodies of water. West Hawk Lake, according to the Government map, is connected with Falcon Lake, but Mr. C. A. Millican, who has seen this connection, states that the water of Hawk Lake drains north-westerly and does not flow into Falcon Lake.

At Ash Rapids the current is sometimes from Shoal Lake into the Lake of the Woods, and sometimes in the opposite direction. At the time of our visit on June 15th, the water was flowing from the Lake of the Woods into Shoal Lake. The water in Shoal Lake is said to rise or fall from eighteen inches to two feet during ordinary years, but in some years much greater fluctuations have been observed.

If Shoal Lake were separated from the Lake of the Woods by a dam at Ash Rapids, its watershed would be insufficient to furnish the quantity of water which will be ultimately required by Winnipeg, without drawing so heavily on Shoal Lake that its level would be lowered, at times, by many feet. This would not be permissible owing to the shallowness of Indian Bay. As a matter of fact, the level of the Lake of the Woods will be maintained by the power dams at Kenora at such a height as will cause its waters to flow into Shoal Lake should there be an unusual draft of water therefrom. Hence, for the ultimate requirements of Winnipeg, the entire watershed of the Lake of the Woods would have to contribute to its water supply. The natural yield of this watershed, however, is so great, in comparison with the needs of Winnipeg, as to render the latter almost a negligible quantity.

The diversion of forty-eight million gallons a day from Shoal Lake for the City of Winnipeg would reduce the water power at Kenora during the dryest periods by only eight horse power for each foot of fall.

QUALITY OF SHOAL LAKE WATER.

From the sanitary standpoint there is little reason to question the purity of the water of Shoal Lake at the present time, as the entire region around it is practically uninhabited save for a few bands of Indians and for occasional hunting parties. The water is very soft in comparison with the water at present supplied to Winnipeg, its hardness, according to the analysis, being not far from 50 parts per million, practically all of which appears to be in the form of carbonates; and the water, in the absence of unusual conditions may, therefore, be termed an excellent one for domestic, boiler and general manufacturing purposes.

If Shoal Lake were adopted as the source of supply, it would be necessary to approach the lake through Snake Lake and Falcon River Valley, as, so far as we have been able to learn, no other route seems favorable.

Falcon River enters Indian Bay at its west end, and the proposed intake would be located about a mile and a half to the east, where the water is about twenty feet deep. The water of Falcon River is intensely colored by the organic matter in the soil of the region which it drains, and at the time of our visit was as dark as strong tea.

The figures given in Table No. 13, Appendix C, and shown diagramatically in Plate 6, show the influence of the Falcon River water on the color of the water of Indian Bay. The color of the water in the middle of Shoal Lake, and even of that at the lower end of the Indian Bay Narrows, is so low as to be practically negligible. Everywhere in the main part of Indian Bay, however, the color was above or very near the permissible limit of 20 and was about 35 at the point of the proposed intake. At the time of our visit the observed

colors at points east of the proposed intake were not excessively high, but there is very good reason to believe that with certain conditions of winds and with high water in Falcon River the color of the water in Indian Bay at the site of the proposed intake might at times increase to 50 or even to 75 or 100. Water of this color would be decidedly objectionable, and in order to insure a supply of continuously light colored water from this source it would be necessary to resort to artificial decolorization.

Owing to the shallowness of Indian Bay, and to its receiving the drainage of swampy areas of large extent, the conditions seem well adapted to produce growths of algæ in the lake at certain seasons of the year, and we believe, judging from experience elsewhere, that the water of this lake may at times become so extensively seeded with growth of these troublesome organisms as to render it offensive with respect to tastes and odors, particularly after flowing nearly one hundred miles through a closed pipe line. Microscopical analysis of samples collected during our visit showed the presence of some of these organisms in small quantities, but it was too early in the season to find them growing extensively.

Considering the high color likely to occur at any time, and the possibility of algæ growths during the hot weather, it is probable that, to render a supply of water from Indian Bay at all times satisfactory, works for purifying the water would be an essential part of the plant. The water, however, could be purified at low cost.

DESCRIPTION OF REQUIRED WORKS.

Three methods of supplying Winnipeg with water from Indian Bay are possible. These are:

First: A gravity supply with conduits of sufficient capacity to supply water to the city as fast as it might be needed at any and all times. This large conduit capacity would be necessary, in a supply of this nature, owing to the topography of the country immediately surrounding Winnipeg. The city lies in a flat, comparatively level plain, there being no hills near enough to permit building a service reservoir to balance the irregularities of draft. A gravity supply for Winnipeg, therefore, would require conduits large enough to supply the water at the maximum rate at which it might be needed at any time, even during fires. Thus, when the average daily consumption in Winnipeg shall reach 9,000,000 gallons per day the conduits must have a discharging capacity of about 25,000,000 gallons per day; and similarly, when the average daily consumption reaches 30,000,000 gallons per day, the conduit capacity must be a little over 60,000,000 gallons; and for the full capacity of 50,000,000 gallons daily the conduits must be capable of delivering water to the city at the rate of at least 90,000,000 gallons per day, otherwise pressures would fall in the city and the benefits of a gravity supply be lost. This peculiar position,

unfortunately, makes a gravity supply of water for Winnipeg prohibitive on account of the great cost of the necessary works, as will be seen by reference to the estimates given hereafter.

Second: A gravity supply could be provided for all purposes excepting for the balancing of hourly rates of maximum consumption and for fire protection, the conduits being made large enough to supply the water at a pressure of seventy pounds per square inch in the city, at a rate corresponding to the maximum daily consumption, the surplus above the ordinary consumption being stored in a reservoir in Winnipeg and being pumped thence into the mains, if necessary, to make up the deficiency during periods of excessive consumption and during fires. This plan, also, is too expensive to be considered.

Third: A supply could be brought from Indian Bay by gravity to a reservoir in Winnipeg and the entire supply be pumped from this reservoir into the mains.

For all three types of supply the intake would be practically of the same nature and would consist of a submerged pipe extending out about a mile and a quarter into the bay.

The gate house, which would be built immediately for the full supply of 48,000,000 gallons daily, would be located near the shore of the lake and would be of masonry construction containing the screens and gates for controlling the entrance of the water into the conduit lines.

The plan proposed for securing a supply for Indian Bay would be to construct the pipe line in three instalments, as in the case of the Winnipeg River project, each line having a daily discharging capacity of twenty-three million gallons, the first line being built immediately, the second when the average daily consumption shall have reached seventeen million gallons, and the third when the average consumption shall have reached twenty-three million gallons daily.

The conduit line would be made up of three sections, the first extending from the intake in the direction of Birch River, a distance of 22.6 miles, the second extending twenty-seven miles further westward, and the third continuing to Winnipeg, a further distance of forty-three miles.

Owing to the different slopes available for the pipe lines in these three sections, the sizes of the pipes would vary, correspondingly, as follows:

Section	Length	Diameters of Pipes if of wood staves	Diameters of Pipes if of riveted steel
First .	119,328 ft	64 inches	70 inches
Second .	142,560 ft	54 inches	57 inches
Third ..	227,000 ft	48 inches	52 inches

The first conduit line would have sufficient capacity to provide for the needs of the city until the average daily consumption reaches 17,000,000 gallons; the addition of the second conduit would provide for an average daily consumption of 33,000,000 gallons, and of the third for 48,000,000 gallons, sufficient for a population of a little over 500,000 people.

The conduits would discharge into a coagulating basin in Winnipeg, to be built in two instalments of 4,000,000 gallons capacity each, the second instalment to be built when the average consumption shall have reached 24,000,000 gallons daily.

The filters, filtered water reservoirs and high duty pumps in Winnipeg would be built of the same capacities as those described for the Winnipeg River supply.

No unusual difficulties would be expected in the construction of these works, with the exception of about ten miles of the pipe line at the east end, including the stretch which would have to be laid in the bed of Snake Lake and through several miles of deep cutting to the east, the greater part of the excavation for which would have to be taken out by dredging. The drainage of the trenches in parts of this line would also require special study in order to facilitate the laying of the pipes. The main effect of these difficult features would be upon the cost of the work, and this has been taken into account in preparing the estimates.

In reaching a decision as to the best manner of developing a supply from Indian Bay or Shoal Lake various studies were made to determine the effect upon the cost, and upon the time when additions to the plant would have to be made, of dividing the pipe line into different capacities and of providing larger storage for filtered water in order to reduce the sizes of the conduits; but the plan here presented, of having the pipe line in three parts, each to be built as needed, and discharging into a reservoir in Winnipeg to be pumped thence into the street mains, is the least expensive and most satisfactory when considered in connection with the minimum outlay in the immediate future and security against interruptions of the supply.

By way of explanation, it may be well to point out more clearly why a gravity supply, or a partial gravity supply, is so much more expensive, both to construct and to operate, than a supply such as is proposed, which contemplates delivering the water to a reservoir on the ground in Winnipeg and then pumping it into the street mains.

For a gravity supply the water must be delivered in the city at sufficient pressure to afford satisfactory service, which we assume to be about seventy pounds per square inch, corresponding to delivering all the water at an elevation of about 165 feet above the streets; and the available fall for the pipe lines would therefore be 165 feet less than for the pipe lines proposed, which deliver the water at ground level. The pipes for the gravity supply would, therefore, have to be made larger on this account to deliver an equal quantity of water. In addition to this, as was explained in Part I, under the chapter describing the basis

for comparing the different projects, the gravity supply pipe lines would have to deliver the water at all times as fast as it might be needed, there being no possible way of providing a balancing reservoir in Winnipeg to equalize the fluctuating rates of consumption, at a height of 165 feet above the ground, whereas with the plan proposed such a balancing reservoir can be constructed at ground level, and the sizes of the pipes reduced to correspond with the maximum daily rates of consumption rather than the maximum rates in addition to fire drafts, which would have to govern the design of pipes for the gravity supply. Furthermore, the pipes for the gravity supply would have to carry the water at much greater pressure than those for the proposed supply, and would have to be made correspondingly stronger to stand this extra head, as well as the shocks due to the checking of the velocity of flow of the ninety miles of moving water in the conduits, incident to sudden changes in the rates of draft. Wood-stave pipe, for example, could not be economically used for the lower portion of the line. In every particular therefore the pipe lines for the gravity supply would be the most expensive. The difference in cost, amounting to several million dollars, between the conduits for the two types of supply, will more than pay for the pumping machinery and reservoir in Winnipeg, and the interest on this difference will amount annualy to more than the cost of pumping all the water into the mains in the city, so that both in first cost and in annual charges the gravity supply is less advantageous than the supply on the plan proposed.

The necessity of filtering the water from Indian Bay or Shoal Lake, particularly at first, may not be imperative, as it might be possible that the troubles with algæ growths, with color and turbidity, would not be so aggravated as the local conditions warrant us in believing they will be; and if this source of supply were adopted, for the many natural advantages which it possesses, filters could be built later, if found necessary.

With a gravity supply of filtered water the filters would, of necessity, be located about twenty miles from Indian Bay; and the estimates of cost have been based on pipes having capacities equal to the maximum daily rates of consumption for the portions between the intake and the filter plant, the first instalment having a capacity of 28,000,000 gallons daily and the second 40,000,000 gallons daily. From the filter plant to the City of Winnipeg the line would be built in two instalments, each capable of delivering the water at the rate of 45,000,000 gallons daily, the filtered water reservoir at the filter plant affording sufficient storage to permit the reduction in the size of the pipe from the plant to the intake.

If, instead of locating the intake at the point proposed in Indian Bay, it were extended about five miles further, passing through the bay and narrows to the open water of Shoal Lake, a supply could be obtained which would probably not require filtration. In Part 6 this matter is more fully discussed.

SUPPLY FROM INDIAN BAY

Summary of Estimates of Cost of Construction and Annual Cost of Operation and Maintenance.

Filtered water delivered by gravity into reservoir in Winnipeg and pumped thence into street mains.

With Wood-Stave Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000	$ 4,223,000.00	$ 338,000.00
24,000,000	7,814,000.00	648,000.00
36,000,000	11,747,000.00	967,000.00
48,000,000	12,357,000.00	1,098,000.00

With Steel Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000	$ 8,979,000.00	$ 604,000.00
24,000,000	17,311,000.00	1,174,000.00
36,000,000	25,798,000.00	1,754,000.00
48,000,000	26,407,000.00	1,886,000.00

Gravity Supply. Filtered—No Pumping.
Wood-Stave and Steel Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000	$ 8,218,000.00	$ 506,000.00
24,000,000	15,859,000.00	982,000.00
36,000,000	16,314,000.00	1,048,000.00
48,000,000	16,601,000.00	1,108,000.00

All-Steel Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000	$12,634,000.00	$ 754,000.00
24,000,000	24,960,000.00	1,493,000.00
36,000,000	25,339,000.00	1,557,000.00
48,000,000	25,627,000.00	1,617,000.00

UNFILT ED SUPPLY FROM SHOAL LAKE.

Water to be delivered into a reservoir in Winnipeg and pumped thence without filtration into the street mains.

Intake to be extended through Indian Bay to the open water of Shoal Lake.

With Wood-Stave Pipe Lines.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000	$ 4,585,000.00	$310,000.00
24,000,000	8,183,000.00	568,000.00
36,000,000	12,345,000.00	859,000.00
48,000,000	12,667,000.00	930,000.00

With Steel Pipes.

Supply in Gallons Daily	Cost of Construction	Annual Cost of Operation
12,000,000	$ 9,180,000.00	$ 569,000.00
24,000,000	17,351,000.00	1,085,000.00
36,000,000	26,097,000.00	1,633,000.00
48,000,000	26,419,000.00	1,704,000.00

PART VI.

Comparison of the Different Supplies

For the purpose of comparing the relative advantages of the different sources of supply, it is necessary to take into consideration:

1. The quality of the water before and after treatment;
2. The time required for the construction of the works;
3. The cost of building and the annual cost of operating the works.

COMPARISON OF THE DIFFERENT SOURCES AS TO QUALITY.

The ideal water for a public water supply is one that is clear, colorless, without taste or odor, free from contamination, and containing only small amounts of such dissolved mineral matters as would tend to make it hard, alkaline or saline.

That a water must be free from contamination and of a safe and wholesome quality is absolutely essential; but such characteristics as color, hardness and turbidity may be present in small amounts without making the water unsuitable for a public supply. It is not often that large quantities of water of an entirely satisfactory character can be obtained without purification, although small supplies which approach the ideal are quite common.

In studying the quality of the waters from the four sources of supply we have compiled all previous available analyses together with others made from samples collected personally during our trips of inspection. The results of these analyses are given in the tables of Appendix C. For convenience of comparison the salient features of the analyses have been summarized in the following table, which gives in round numbers the probable maximum, minimum and average for each item, first for the waters in their natural condition, and second for the same waters after having been subjected to appropriate treatment. In the case of the present supply, however, the figures which represent the water after treatment are based on the results actually

obtained by the present softening plant rather than upon the results which might be obtained if the process were more nearly perfect.

TURBIDITY.

In explanation of the table it may be said that the term "turbidity" refers to the visible, finely-divided matter suspended in the water, such as clay, silt, microscopic organisms, or fragments of organic matter.

Turbidity is expressed in terms of parts per million, by weight, of suspended matter of a standard degree of fineness. The methods of measuring it are essentially optical. In a water which has a turbidity of 7, for example, it would be just possible to see a pin immersed three feet seven inches below the surface; while, if the turbidity were 100, the pin could not be seen at depths greater than four inches, and, if it were 1,000, would be invisible at depths greater than about three-fourths of an inch.

COLOR.

The technical meaning of the word "color" as applied to a drinking water relates not to suspended matter (although particles in suspension may give the water a colored appearance), but to organic matter in solution. By contact with decaying vegetation of swamps, peat, muskegs, etc., a water becomes colored or stained, sometimes to a considerable extent. Color is objectionable only by way of making the water unattractive in appearance, and for this reason it is not required that water be absolutely colorless, but only sufficiently free from color to be inconspicuous. A color of about 20 on the commonly accepted platinum scale is generally considered as the limit which should not be exceeded.

HARDNESS.

The hardness of water is a term expressing the amount of lime and magnesia salts dissolved in the water. These are generally in the form of carbonates or sulphates, the former causing the temporary hardness productive of a soft scale in a boiler, and the latter the permanent hardness productive of a hard scale. The carbonates or temporary hardness appear in the analyses as "alkalinity," and the sulphates, or permanent hardness, as "incrustants;" together they make up the total hardness.

The use of hard water is not only a great inconvenience in the household, but it is also expensive, as it necessitates the use of large quantities of soap and washing powders, with the consequent destruction of fabrics washed in the laundry. It has been estimated that every part per million of hardness costs the consumer 12 cents per million imperial gallons of water used. Winnipeg water, as it is now de-

livered, part softened and part not, costs the consumer therefore 300x12c. or $36 per million gallons, which for the whole city, at a rate of consumption of four million gallons daily, amounts to $53,000 per year.

Popular ideas as to what constitutes a hard or a soft water are much influenced by local conditions. The following figures, however, represent common usage of the term "hard":

Hardness.	Parts per Million of "Hardness."
Very soft	0-10
Soft	10-25
Slightly hard	25-50
Hard	50-100
Very hard	100-200
Excessively hard	200-500
Mineral water	500-upwards

CHLORINE.

The chlorine of the analysis stands largely for common salt, that is, sodium chloride, but includes also the chlorides of calcium and magnesium, if present. Chlorides in water, in large amounts, are objectionable as they are corrosive and tend to cause pitting in boilers and to injure plumbing fixtures by facilitating galvanic action. No permissible limit for chlorides has ever been placed, but quantities higher than about twenty-five parts per million of chlorine are generally considered as undesirable, and in many cities earnest efforts are made to keep the chlorine considerably below this figure. Chlorine also has some significance from a sanitary standpoint, but in the case of the region around Winnipeg this significance is rendered of no effect because of the mineral origin of the chlorine present in the natural waters.

TASTES AND ODORS.

The tastes and odors of waters are qualities which need no particular explanation in connection with the table. It may be remarked, however, that most lake and river waters have a vegetable or peaty odor, which varies roughly with the color, and that lake waters often have, in addition, odors which are quite disagreeable, due to the presence of algæ and other microscopic organisms. Excessive amounts of mineral matter often impart noticeable tastes.

For the sake of simplicity no attempt has been made in the table to separate the various factors which together determine the sanitary quality; but data on these matters are included in Appendix C

SUMMARY OF LEADING CHARACTERISTICS OF THE WATER OF THE SOURCES OF SUPPLY INVESTIGATED.

Waters in their Natural State.

	Present Supply of Winnipeg	Ground Water north of Winnipeg			Red River at St. Norbert			Winnipeg River at Seven Portages			Indian Bay of Shoal Lake			Shoal Lake		
	Average	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Turbidity	0	0	0	0	5	50	3500	5	10	50	0	3	25	0	2	10
Color	0	0	0	0	10	20	60	40	50	60	20	35	75	3	5	15
Hardness	475	400	600	800	150	250	350	0	40	0	0	50	0	0	50	0
Alkalinity	350	350	500	600	120	180	250	0	40	0	0	50	0	0	50	0
Incrustants	125	50	100	200	30	70	100	0	0	0	0	0	0	0	0	0
Chlorine	245	15	35	100	5	20	75	0	2	0	0	2	0	0	2	0
Odor	None	None			Distinct Veg.			Distinct Veg.			Slight Vegetable			Slight		
Taste	Distinct saline	District mineral			Distinct Veg.			Distinct Veg.			Slight Vegetable			Slight		
Possibility of algae growth	None	None			Very Slight			Slight			Strong			Slight		
Sanitary quality	Satisfactory	Satisfactory			Unsatisfactory			Not satisfactory			Satisfactory			Satisfactory		
Quality for boiler purposes	Unfit	Unfit			Unfit			Good			Good			Good		

Waters after Proper Treatment.

	Present Supply of Winnipeg	Ground Water north of Winnipeg			Red River at St. Norbert			Winnipeg River at Seven Portages			Indian Bay of Shoal Lake			Shoal Lake		
	Average	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Turbidity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10
Color	0	0	0	0	0	5	10	0	5	10	0	5	10	3	5	15
Hardness	210	0	75	0	0	75	0	0	40	0	0	50	0	0	50	0
Alkalinity	90	0	60	0	0	60	0	0	30	0	0	40	0	0	50	0
Incrustants	120	0	15	0	0	15	0	0	10	0	0	10	0	0	0	0
Chlorine	245	0	35	0	5	20	75	0	2	0	0	2	0	0	2	0
Odor	None	None			Practically none			Practically none			Practically none			Slight		
Taste	None	None			Practically none			Practically none			Practically none			Slight		
Sanitary quality	Satisfactory	Satisfactory			Satisfactary			Satisfactory			Satisfactory			Satisfactory		
Quality for boiler uses	Unfit	Fair			Fair			Good			Good			Good		

The analyses of samples from the four sources which we have investigated indicate that none of these waters in their natural state, not even that from Shoal Lake if taken from Indian Bay, comes within the limits which we believe would be satisfactory to the people of Winnipeg.

The present supply has several good qualities; it is cool, clear and colorless, and it is safe and free from contamination, but is unsuitable for manufacturing uses because of its hardness and its salinity.

The hardness of water in different localities depends upon the prevalence of limestone and of carbonic acid. The conditions at Winnipeg are especially favorable for the production of a hard water, as great beds of limestone underlie the region, and above these are thick layers of peat, muskeg, and loam, rich in organic matter, the source of carbonic acid. The presence of large amounts of carbonic acid in the city well water has been shown by analysis.

In order that an idea may be obtained of the hardness and salinity of the Winnipeg water as compared with the water supplies of other cities, the following list has been compiled:

TABLE SHOWING THE HARDNESS AND CHLORINE IN VARIOUS PUBLIC WATER SUPPLIES.

Parts per Million.

State	City	Alkalinity (temporary hardness)	Incrustants (permanent hardness)	Total Hardness	Chlorine
United States					
Maine	Augusta	15	5	20	1.0
New Hampshire	Concord	..	..	9	1.3
Vermont	Burlington	..	..	45	2.0
Massachusetts	Boston	..	..	15	3.0
Massachusetts	Springfield	..	..	8	1.3
Rhode Island	Providence	..	..	7	5.0
Connecticut	New Haven	20	10	30	3.0
New York	New York (Croton)	30	5	35	2.0
New York	New York (New Catskill)	13	2	15	1.2
New York	Brooklyn (Ridgewood)	16	17	33	15
New York	Albany	54	10	64	3.5
New York	Watertown	23	11	34	1.0
New York	Oswego	98	5	98	5.5
New York	Buffalo	95	5	100	5.5
New Jersey	Trenton	37	22	59	3.0
New Jersey	Jersey City	36	5	41	4.5
Maryland	Baltimore	..	..	..	6.0
Pennsylvania	Philadelphia	116	63	179	15.0

TABLE SHOWING HARDNESS, ETC.—(*Continued*).

State	City	Alkalinity (temporary hardness)	Incrustants (permanent hardness)	Total Hardness	Chlorine
Dist. Columbia..	Washington	80	18	98	4.0
Pennsylvania. ..	Pittsburgh	29	7	36	22.0
Virginia	Norfolk	7	58	65	75.0
North Carolina .	Wilmington	10	15	25	7.0
South Carolina .	Charleston	14	38	24	26
South Carolina .	Columbia	22	..	18	4.0
Florida	Starke	154	9	168	20.0
Alabama	Birmingham	37	..	37	1.5
Ohio	Columbus	200	135	335	12
Ohio	Toledo	150	50	200	50
Ohio	Cleveland	90	15	105	8
Kentucky	Louisville	65	18	83	12
Louisiana	New Orleans	79	14	93	15
Illinois	Chicago	..	..	..	1.8
Illinois	Quincy	90	13	103	..
Minnesota.	St. Paul	..	..	143	1.0
Minnesota.	Minneapolis	151	..	136	1.0
Minnesota.	Duluth	..	..	35	1.0
California	San Francisco	21	12	33	..
Wisconsin	Superior	45	0	45	1.5
Michigan.	Battle Creek	244	..	188	3.0
Michigan	Detroit	..	..	80	1.5
Canada					
Quebec	Montreal	..	..	50	2.5
Ontario	Toronto	..	..	100	8.5
Ontario	Ottawa	..	..	25	1.5
Ontario	Peterboro	63	3	36	2.2
Manitoba	Winnipeg	186	118	304	240.0

It will be seen from this table that few, if any, large cities in Canada or the United States have a public water approaching in hardness and salinity that supplied to Winnipeg.

The hardness of the present supply could be reduced to a reasonable degree by softening with lime and soda, but the salinity could not be eliminated by any practicable form of treatment; and the salinity remaining after the hardness had been reduced might be more troublesome than before. No form of purification therefore can render the local ground water wholly satisfactory as a public supply.

In the ground water to the north the chlorides are much lower than in the present supply, and although they are still rather high when compared with most public supplies, they are not high enough to prohibit the use of the water. The water is hard, but the hardness could be removed to a satisfactory degree. This water after softening would furnish an acceptable supply so far as quality is concerned.

The water of the Red River is contaminated to a very slight extent by sewage, and at times to a considerable extent by manure thrown on the banks and deposited on the ice. In the spring and early summer the river water is muddy, and, indeed, is never clear enough for use without being filtered, while at all times it is somewhat colored and has a vegetable taste. All of these objectionable qualities could be reduced to a satisfactory degree by sedimentation and filtration, and the water rendered safe and wholesome, absolutely clear and practically colorless. The water is hard, however, and slightly saline. It would require softening to make it satisfactory. The softening process and general purification would be naturally conducted as one series of operations, and the result would be a water just about equal in quality to that of the ground water north of the city after softening.

Sometimes the salinity and hardness of the Red River water are quite low, that is, when the river is in flood; but at low stages, when the percolation of ground water into the river is greater, the hardness and chlorine increase materially. Undoubtedly the Red River water can, by the use of proper methods of purification, be made into an acceptable supply.

The Winnipeg River water is relatively soft. It would not require softening; in fact, its hardness is less than the probable hardness of the Red River water, or the ground water, after softening. Its chlorine is very much lower than that of the Red River water or any of the ground waters within a hundred miles of Winnipeg, and is entirely negligible. The water has rather a high color, and possesses a noticeable vegetable taste. It is also open to some contamination at Kenora and elsewhere, and, while this is very small in amount at present, it is likely to increase in the future. This water, therefore, requires purification in order to render it acceptable. It would be an easy water to treat, however, and the purified water would very closely approach the requirements of an ideal public supply.

The water of Shoal Lake at Indian Bay is soft, and in this respect resembles the water of the Winnipeg River. In its natural condition, it is softer than the Red River water or than the ground water would be after softening. Its chlorine is a negligible quantity. It is practically uncontaminated, as the entire region for miles around is uninhabited. From the sanitary standpoint filtration is not now required, as the natural water is reasonably safe and wholesome. The water, however, possesses a noticeable color, due to the effect of the Falcon River, which drains a muskeg region. Indian Bay is comparatively

shallow, the depth of water for some miles from the proposed intake averaging not more than twenty feet. In many ways the conditions for growths of algæ and other microscopic organisms which impart bad tastes and colors to water are favorable, although their season of troublesome growth would probably be short. The Indian Bay water used in its natural condition would furnish a safe and wholesome supply, and it would be soft, but it would not come up to the required standards for clearness, color or taste unless it were filtered; it would be an easy water to treat, however.

If the water were to be taken from the main part of Shoal Lake rather than from Indian Bay, the difficulties regarding turbidity and color would be removed, as would probably also the dangers of disagreeable odors and tastes; sufficient data, however, are not at hand to give assurance that that water would always be satisfactory in these respects. Such data could only be obtained by a systematic microscopical examination of the water through the fall months, when, if the presence of objectionable organisms were then not detected, it might be safe to assume that no serious trouble need be feared in the future and that the water could safely be used without purification.

Considered from the standpoint of the quality of the water in its natural condition and taking into account the use of the water for all purposes, the Shoal Lake water is unquestionably the best source of supply. The Red River water needs softening and purification from the sanitary standpoint, the Winnipeg River water needs decolorization, and the Indian Bay water needs decolorization and possibly æration to remove the effects of algæ growths. The water of Shoal Lake proper, unless subject to algæ growths, would be satisfactory without treatment. By proper treatment the water of any of the three sources could be made satisfactory and acceptable. The water of the Winnipeg River, of Indian Bay, or of Shoal Lake, could either one be made more acceptable than that of the Red River, because of their lower salinity and hardness. Between the Winnipeg River filtered and the Indian Bay water filtered there is little to choose, but we consider the Winnipeg River water somewhat better, as it is slightly softer, and is less likely to be affected with odors caused by algæ growths.

COMPARISON AS TO TIME REQUIRED FOR CONSTRUCTION.

For each of the supplies considerable preliminary work would be necessary before the plans and specifications could be prepared and the contract let. The field and office work required for the preparation of plans for the Red River supply could be completed in from six to eight months, while for either the Winnipeg River or Shoal Lake supplies probably a full year would be consumed.

The actual time required for the construction of the work would be, under favorable conditions, and if the work were energetically

pushed, for the Red River supply about two years, for the Winnipeg River supply about three years and for the Shoal Lake supply about four years; with the possibility that a year longer might be required in each case should the seasons be unfavorable or should unforeseen difficulties arise.

COMPARISON AS TO COSTS OF CONSTRUCTION AND OPERATION.

In comparing the costs of the various projects it is necessary to take into consideration—

1. The cost of construction of the first instalment of the works;
2. The cost of construction of enlargements as they are needed;
3. The interest on the investment;
4. The depreciation of the perishable parts of the plants;
5. The costs of maintenance and operation.

The first two of the above items concern the construction cost only; the last three, the annual charges for maintenance, operation and administration.

Under the construction costs should be considered, also the difficulties that would be presented in the delivery of materials and in the construction of the works, while under the operating costs should be considered the relative simplicity or difficulty of maintaining the plants in working order and in successful operation. In making up the estimates all these points have been considered and allowed for.

In order to make fair comparisons on the basis of costs, it has seemed necessary that the raw waters should be in all cases so treated as to render them equally desirable in point of quality for domestic and manufacturing purposes, and if this were impossible to make the less desirable at least good enough to be acceptable. The effect of this assumption has been to provide, in the case of the Red River Supply, for filtration and softening. In the case of the Winnipeg River and Indian Bay supplies filtration only would be required with possibly æration in the case of the Indian Bay water.

In order to facilitate comparisons at different stages of development, the costs are stated in the estimates for plants capable of yielding sufficient water to satisfy all demands for domestic, commercial and manufacturing consumption, in addition to fire drafts, when the average daily consumptions shall have reached 12,000,000, 24,000,000, 36,000,000 and 48,000,000 gallons respectively. These do not represent in the case of the Winnipeg River and Shoal Lake supplies, as regards the pipe lines, the capacities for which the works would be built. The divisions would be convenient for the installations of pumps, filters and reservoirs, which can be put up quickly and at about a uniform pro rata cost for increases in capacity, but the pipe lines

being so long and so costly should be built at the first installation with a capacity of 23,000,000 gallons, sufficient to take care of the fluctuations of draft for an average daily supply of about 17,000,000 gallons. In fact, were it feasible on financial and other grounds, it would be cheaper in the end to build the pipe lines in two installations of 34,000,000 gallons daily capacity each, instead of three of 23,000,000 gallons as proposed; but such a division would require too great an initial outlay and would introduce the risk that there would be a period of several years when the city would be entirely dependent upon one pipe line, as it would not be wise and would probably be impossible to develop the ground water supply to the necessary extent to serve as a reserve in case of accident to so large a pipe line.

In comparing the costs of the different plans the annual cost of operation is of equal and, in some cases, even greater importance than the cost of construction, and much study has been given in each case to arrive at these costs as accurately as possible. Frequently, in such investigations, it develops that the most expensive plants to build cost the least to maintain and operate.

In the table immediately following are given summaries of the estimates of the costs of building the various different works; the detailed estimates will be found in Appendix D.

SUMMARY OF ESTIMATES.

Costs of Construction.

Supply	Capacity of Works (gallons per day)			
	12,000,000	24,000,000	36,000,000	48,000,000
Extension of present ground water supply	$2,800,000	$5,000,000	$7,500,000	$9,700,000
Red River, filtered and softened	2,168,000	3,458,000	5,413,000	6,870,000
Red River, filtered but not softened	2,139,000	3,400,000	5,327,000	6,755,000
Winnipeg River, filtered, wood stave pipes	3,862,000	6,538,000	9,593,000	10,519,000
Winnipeg River, filtered, steel pipes	6,050,000	10,915,000	16,159,000	17,084,000
Indian Bay, filtered, pumped in Winnipeg, wood stave pipes	4,223,000	7,814,000	11,747,000	12,357,000
Indian Bay, filtered, pumped in Winnipeg, steel pipe lines	8,979,000	17,311,000	25,798,000	26,407,000
Indian Bay, filtered, gravity supply, no pumping, wood stave and steel pipes	8,218,000	15,859,000	16,314,000	16,601,000
Indian Bay, filtered, gravity supply, no pumping, steel pipe lines	12,634,000	24,960,000	25,339,000	25,627,000
Shoal Lake, not filtered, pumped in Winnipeg, wood stave pipe lines	4,585,000	8,183,000	12,345,000	12,667,000
Shoal Lake, not filtered, pumped in Winnipeg, steel pipe lines	9,180,000	17,351,000	26,097,000	26,419,000

Annual Costs of Operation and Maintenance.

Supply	Capacity of Works (gallons per day).			
	12,000,000	24,000,000	36,000,000	48,000,000
Extension of present ground water supply	$435,000	$945,000	$1,400,000	$1,870,000
Red River, filtered and softened	359,000	671,000	1,018,000	1,343,000
Red River, filtered but not softened	234,000	423,000	646,000	847,000
Winnipeg River, filtered, wood stave pipes	343,000	630,000	922,000	1,108,000
Winnipeg River, filtered, steel pipes	468,000	870,000	1,292,000	1,474,000
Indian Bay, filtered, pumped in Winnipeg, wood stave pipes	338,000	643,000	967,000	1,096,000
Indian Bay, filtered, pumped in Winnipeg, steel pipe lines	604,000	1,174,000	1,754,000	1,886,000
Indian Bay, filtered, gravity supply, no pumping, wood stave and steel pipes	506,000	983,000	1,048,000	1,108,000
Indian Bay, filtered, gravity supply, no pumping, steel pipe lines	754,000	1,493,000	1,557,000	1,617,000
Shoal Lake, not filtered, pumped in Winnipeg, wood stave pipe lines	310,000	568,000	850,000	930,000
Shoal Lake, not filtered, pumped in Winnipeg, steel pipe lines	569,000	1,095,000	1,633,000	1,704,000

An inspection of the above tables shows at once that some of the supplies are more desirable than others. Thus, while the extension of the ground water supply would cost less than the introduction of the Shoal Lake supply, the annual costs of operation, due to multiple pumping and the necessity of softening, make it the most expensive of all the supplies to maintain, the annual costs, even for the first installations, being prohibitive. A ground water supply, therefore, while eminently the best practicable for former conditions, thus proves impracticable when dealing with such large quantities of water as must be supplied to Winnipeg in the not far distant future.

It has previously been explained that the development of a ground water supply in the immediate vicinity of Winnipeg would be undesirable on the score of the quality of the water, which, when the water were softened, would contain about ten times the permissible limit of saline constituents for an acceptable boiler water.

Comparing now the Red River supply with that from Winnipeg River, we find that, although the costs of construction for the different capacities are less for the Red River supply, the annual costs of operation are higher, due to the large quantities of chemicals required in the softening process.

The gravity supply from Indian Bay, owing to its great cost, the reasons for which have previously been made apparent, cannot be considered as entering into the comparison.

Apparently there is not much choice between the Shoal Lake supply filtered and pumped in Winnipeg and the filtered Winnipeg River supply, when compared on the basis of annual costs of operation; but there is a difference of from $400,000 to $1,800,000 in favor of the latter supply when compared on the basis of costs of construction, and it is difficult to see in what particular the Indian Bay supply is worth the difference in cost.

It is further to be borne in mind that the Winnipeg River pipe lines, lying near the Molson cut-off, the main line of the C.P.R., the Lac du Bonnet Branch, and the tramway from Whitemouth to the Winnipeg River pumping station (provisions for which have been made in the estimates), would be easily accessible at all points in case repairs were suddenly necessary, whereas the Shoal Lake line would, after leaving the G. T. P. R., lie for half its total length in a country at times almost impassable, and where the delivery of materials for repairs would be at times very difficult and might require considerable time.

As to difficulties of construction, there are none on either line that cannot readily be overcome, and the estimates of cost have been made to take these matters into consideration. Either line is practicable, as is also the gravity supply from Indian Bay.

As to difficulties in operation the balance must fall in favor of the Winnipeg River line, owing to its accessibility in case repairs become necessary.

In the case of the Shoal Lake supply, even should the intake be extended some five miles further than proposed, passing through the Indian Bay Narrows to the open water of Shoal Lake, and should the construction of filters be omitted, the first cost of the works would still be from $1,000,000 to $2,000,000 greater than the cost of the Winnipeg River supply, though the annual cost of operation would be somewhat less.

Taking into consideration, however, the possibility of the use of cheap electrical power for pumping at the Winnipeg River station and the smaller initial cost of construction, the Winnipeg River supply is still the more desirable.

Summarizing briefly the advantages and disadvantages of the different supplies it may be said:

1. The permanent extension of the present ground water supply of the city is not advisable on account of the inferior quality and questionable quantity of the water obtainable;

2. The extension of the ground water supply, by developing the territory further north, is not advisable on account of the excessively large cost of operation and maintenance as compared with other available methods, and also on account of the uncertainty as to the quantity of water which could thus be secured;

3. The development of a softened and filtered supply from the Red River is not advisable on account of the high cost and greater difficulties of operation and maintenance, as compared with other available

methods, and the fact that water so treated would still be less desirable, in point of quality, than that which can be secured from the more distant sources;

'. The development of a supply from the Red River, filtered, but not softened, is not advisable, as the water would be too hard to be satisfactory for boiler and laundry uses, and would, indirectly, cost more to the consumers than the softened water;

5. A gravity supply from Shoal Lake, without pumping, is not advisable on account of the great costs of construction and operation, which, in each case are much in excess of the costs of a supply taken to Winnipeg by gravity and thence pumped into the street mains.

6. As between a filtered supply from Winnipeg River, a filtered supply from Indian Bay and an unfiltered supply from the open water of Shoal Lake, a choice would have to be made largely on other grounds than those of the quality of the water or the costs of operation and maintenance. On its face the unfiltered supply from Shoal Lake would seem to be the least expensive as to annual cost of operation; but, if the possibility of operating the Winnipeg River pumping station with cheap electrical power, the greater accessibility of the Winnipeg River pipe line for inspection and repairs, the shorter time required for installation, and the smaller investment necessary, are taken into consideration, the advantages weigh most heavily in favor of the Winnipeg River supply. The unfiltered Shoal Lake supply would be somewhat simpler to operate; this is the only point in which this supply is better than that from Winnipeg River. On the other hand, the Shoal Lake supply would take at least a year longer to build, would cost nearly $1,000,000 more to construct for the initial, and $2,000,000 more for the final installation and would be less accessible for inspection and repairs.

The cost of a satisfactory supply of good water for Winnipeg, owing to the unfavorable natural conditions, is necessarily larger than usual for cities of its size, and therefore a saving in first cost is of relatively greater importance than would otherwise be the case.

In view of the foregoing considerations we therefore believe that it would be for the best interests of the City of Winnipeg to secure its future supply from the Winnipeg River, taking the water from above the Seven Portages and providing for its filtration and for pumping the filtered water into the street mains in Winnipeg.

JAMES H. FUERTES,
R. S. LEA,
J. E. SCHWITZER,
GEORGE C. WHIPPLE.

APPENDIX A.

TABLE I.

Population of Winnipeg, Canada.

(From Records of the Assessors' Office).

Year	Population	Remarks
1874....	1,869	Four Wards.
1875....	2,961	
1876....	3,000	
1877....	2,722	
1878....	3,180	
1879....	4,113	
1880....	6,178	
1881....	6,245	
1882....	15,000	Estimated.
1883....	20,000	Estimated Six Wards, area 12,750 acres.
1884....	16,694	
1885....	19,574	Taken by Wards.
1886....	19,525	
1887....	21,257	
1888....	22,098	
1889....	21,328	
1890....	23,000	
1891....	24,068	
1892....	29,182	Including 3,000 floating.
1893....	32,119	" " "
1894....	34,954	" " "
1895....	37,124	" " "
1896....	37,983	" " "
1897....	38,733	" " "
1898....	39,384	" " "
1899....	40,112	" " "
1900....	42,534	" " "
1901....	44,778	" " "
1902....	48,411	" 4,000 "
1903....	56,741	" " "
1904....	67,265	" 4,500 "
1905....	79,975	" 2,500 "
1906....	97,749	No floating.
	101,057	Including two new wards added area—13,990 acres.
1907....	111,717	(Report May 13, 1907).

Table II.

Table Showing the Growth of the City of Winnipeg, Canada, from 1900 to 1907 Inclusive.

Date	Estimated Population Including Floating Population	Estimated Resident Population	Number of Water Services	Number of Sewer Connections	Estimated Number of Dwellings	School Attendance
1900 . . .	42,534	39,534	.....	2,356	[illegible]	7,500
1901 . . .	44,778	41,778	.....	2,737	7,400	.....
1902 . . .	48,411	44,411	3,474	3,45[illegible]	7,950	.....
1903 . . .	56,741	52,741	5,065	4,312	[illegible],730	9,500
1904 . . .	67,265	62,565	7,318	5,626	10,080	10,308
1905 . . .	79,975	77,475	11,654	7,985	12,[illegible]40	11,675
1906 . . .	.....	101,057	15,251	10,362	13,360	13,445
1907 . . .	.....	111,717	.....	.....	16,000	.....

Table II.—(*Continued*).

Date	Post Office Revenue	Bank Clearings—million dollars	Gross Earnings of Street Railway	Amount of Assessable Property—million dollars	Inland Revenue Collections	Waterworks Revenue
1900 . .	....	$107	......	$25	$537,958	......
1901 . .	$125,000	...	......	26	637,881	......
1902 . .	156,734	188	$199,730	29	777,457	......
1903 . .	201,906	246	287,270	36	914,189	$104,220
1904 . .	256,519	295	407,540	48	1,001,109	156,541
1905 . .	319,378	370	551,651	63	1,150,198	185,809
1906 . .	418,912	505	726,730	81	....	175,102
1907 . .	....	...	......	..	....	205,072 Estim't'd

Table III.

Estimates of Population and Water Consumption, Winnipeg, Canada.

Year	*Population	Per Capita Consumption—imperial gallons daily	Average Daily Consumption—million gallons	Maximum Daily Consumption—million gallons, average x 1.4	Excess of Maximum Hourly Rate at 60 gallons per capita—million gallons daily	Maximum Hourly Rate—million gallons daily	Number of Fire Streams Required
1910 . .	150,000	60	9.0	12.6	9.0	18.0	35
1915 . .	220,000	66	14.5	20.3	14.5	29.0	42
1920 . .	300,000	74	22.2	30.1	19.3	41.5	50
1925 . .	385,000	80	30.8	43.0	24.2	55.0	55
1930 . .	475,000	83	39.4	55.2	29.4	69.8	60
1935 . .	580,000	85	49.3	69.0	34.5	83.9	65

*Population will reach 250,000 in 10 years, *i. e.*, in 1917.

Population will reach 500,000 in 24 years, *i. e.*, in 1931.

Table III.—(*Continued*).

Year	Allowance for Fire Service—million gallons	Extreme Maximum Hourly Rate including Fire Service—million gallons daily	Allowed Maximum Hourly Rate, reasonable allowance for Fire Service—million gallons daily	Per cent. which Hourly Rate is of Average Daily Consumption	Per cent. which Excess Requirements would be of Average Daily Consumption
1910	11.0	29.0	25.0	278	332
1915	12.6	41.6	35.0	241	279
1920 ...	15.0	56.5	47.0	219	252
1925	16.5	71.5	60.0	195	234
1930	18.0	86.8	74.5	189	223
1935	19.5	103.4	90.0	183	210

APPENDIX B.

TABLE IV.

Statistics of Yield of Wells and Water Pumped to the City, Monthly Averages, Winnipeg, Canada, June, 1901, to May, 1907.

(Million Imperial Gallons per Day).

1901	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Quantity Softened	Pumped to City	Maximum daily
January	....	....	....	....	....	....	....
February	....	....	....	....	....	....	....
March	....	....	....	....	....	....	....
April	....	....	....	....	....		....
May	....	....	....	....	....		....
June	....	....	....	....	....	0.63	....
July	....	....	....	....	....	1.55	....
August	....	....	....	....	....	1.67	....
September ...	....	....	....	....	....	1.49	....
October	....	....	....	....	....	1.63	....
November ...	....	....	....	....	....	1.60	....
December ...	....	....	....	....	....	1.46	....
Average	....	....	....	....	....	1.43	....
1902							
January	....	....	....	....	....	1.01	....
February	....	....	....	....	....	2.11	....
March	....	....	....	....	....	1.93	....
April	....	....	....	....	....	1.49	....
May	....	....	....	....	....	1.33	....
June	....	....	....	....	....	1.30	....
July	....	....	....	....	....	1.88	....
August	....	....	....	....	....	1.76	....
September...	....	....	....	....	....	1.37	....
October	....	....	....	....	....	1.36	....
November ...	....	....	....	....	....	1.24	....
December. . .	....	....	....	....	....	1.28	....
Average						1.51	

Table IV.—(*Continued*).

1903	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Quantity Softened	Pumped to City	Maximum daily
January	....	....	....	....	1.36	1.27	....
February	....	....	....	....	1.55	1.49	....
March	....	....	....	....	1.37	1.53	....
April	....	....	....	....	1.50	1.46	....
May	....	....	....	....	1.44	1.47	....
June	....	....	....	....	1.70	1.84	....
July	....	....	....	....	1.73	1.74	....
August	....	....	....	....	1.52	1.63	....
September	....	....	....	....	1.58	1.73	....
October	....	....	....	....	1.53	1.96	....
November	....	....	....	....	1.60	1.82	....
December	....	....	....	....	1.55	1.81	....
Average	....	....	....	....	1.53	1.65	....
1904							
January	....	....	....	....	1.66	1.58	....
February	....	....	....	....	1.73	1.83	....
March	....	....	....	....	1.60	1.68	....
April	....	....	....	....	1.51	1.46	....
May	....	....	....	....	1.57	1.74	....
June	....	....	....	....	1.82	1.79	....
July	....	....	....	....	1.88	1.94	....
August	....	....	....	....	1.94	2.12	....
September	....	....	....	....	2.06	2.12	....
October	....	....	....	....	1.74	2.72	....
November	....	....	....	....	1.95	2.49	....
December	....	....	....	....	2.08	2.55	....
Average	....	....	....	....	1.79	2.00	....
1905							
January	....	....	....	....	2.14	2.40	4.76
February	....	....	....	....	2.48	2.64	3.55
March	....	....	....	....	1.88	2.34	3.42
April	....	....	....	....	2.01	2.21	2.72
May	....	....	....	....	2.13	2.21	3.48
June	....	....	....	....	2.04	2.90	4.12
July	....	....	....	....	2.35	3.19	4.32
August	....	....	....	....	2.30	3.12	3.75
September	....	....	....	....	2.19	3.16	4.25

TABLE IV.—(*Continued*).

1905	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Quantity Softened	Pumped to City	Maximum daily
October	....	....	....	....	2.24	2.95	3.57
November. . .	....	....	....	....	2.17	3.04	3.50
December. . .	....	....	....	....	2.31	3.32	3.54
Average	....	....	....	....	2.18	2.79	....

1906	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Quantity Softened	Pumped to City	Maximum daily
January	....	....	....	....	2.25	2.92	3.34
February	....	....	....	....	2.29	2.90	3.60
March	....	....	....	....	2.42	2.97	3.88
April	....	....	....	....	2.36	3.04	3.54
May	....	....	....	....	2.41	3.12	3.50
June	....	3.44	....	....	2.38	3.10	3.52
July..	....	3.46	0.42	....	2.42	3.51	4.10
August	....	3.37	0.38	....	2.29	3.36	4.14
September. . .	....	3.25	0.48	....	2.41	3.06	3.98
October	....	3.24	*	....	2.45	3.25	3.55
November. . .	....	3.17	....	....	2.31	3.04	3.20
December. . .	....	3.00	0.55	0.94	2.35	3.39	3.08
Average	....	....	....	....	2.35	3.18	....

*—Meter not working.

1907	Well No. 1	Well No. 2	Well No. 3	Well No. 4	Quantity Softened	Pumped to City	Maximum daily
January	....	3.16	0.51	0.95	2.04	3.81	4.88
February	....	3.08	0.52	0.90	2.48	3.88	4.97
March	....	2.90	0.58	0.84	2.42	3.54	4.54
April	....	3.10	....	*0.98	2.33	3.70	4.56
May	....	....	....	....	2.45	4.05	5.00
June	....	....	....	....	....	....	....
July	....	....	....	....	....	....	....
August	....	....	....	....	....	....	....
September. . .	....	....	....	....	....	....	....
October	....	....	....	....	....	....	....
November. . .	....	....	....	....	....	....	....
December. . .	....	....	....	....	....	....	....
Average	....	....	....	....	2.33	3.80	....

*—Not working.

TABLE 5.

Summary of Analyses showing Mineral Constituents.—Well Water—Present Supply at Winnipeg.

Parts per Million.

Date	Sample	Total Solids	Chlorine	Total Hardness	Alkalinity	Incrustants	Magnesium	Iron	Free Carbonic Acid	Analyst
1901	Well No. 1 before softening	....	242	565	361	204	98	....	....	Kenrick
1901	" "	....	239	546	374	172	70	....	22	Handy
1904	" "	991	251	486	338	148	67	....	....	"
1905 Apr. 3 ...	" "	1055	235	492	364	128	67	0.12	....	Whipple
1901 June 28...	" "	....	242	510	....	....	68	....	....	"
1905 Apr. 3....	Well No. 1 after softening	785	234	200	80	120	28	0.00	....	"
1901 June 28 ..	" "	....	242	231	....	....	43	....	....	"
1906 Mar. 31...	Well No. 2 before softening	1116	248	452	328	124	....	....	....	Smart
1907 Apr. 17...	" "	1240	247	473	358	115	....	....	....	"
1906 Jan.	" "	....	....	485	300	125	71	....	....	"
1907 June......	" "	1097	248	470	352	118	57	0 20	33	Whipple
1907 Apr. 17...	Well No. 2 after softening	1020	250	384	261	123	....	....	....	Smart
1907 June......	" "	843	250	225	92	133	33	0.10	18	Whipple
1907 June......	Well No. 3	980	202	465	348	117	59	0 30	28	"
1907 June......	Well No. 4	1015	222	475	342	133	50	0.30	26	"
1907 June......	Well No. 5	1295	254	500	384	116	64	1 50	25	"
1908 Mar. 8....	Tap in Winnipeg	1128	243	411	290	120	....	....	....	Smart
1908 Mar. 22...	" "	920	245	294	109	125	....	....	....	"
1905 Apr. 10...	" "	604	....	184	77	107	....	....	....	"
1908 Nov. 1....	" "	....	243	290	....	....	....	....	....	"
1905 Dec. 20...	" "	864	246	325	213	112	....	....	....	"
1905 Apr. 11...	" "	....	....	187	80	107	....	....	....	"
1905 Apr. 19...	" "	....	....	203	92	111	....	....	....	"
1905 Apr. 26...	" "	....	....	169	58	111	....	....	....	"
1905 Apr. 28...	" "	....	....	190	88	111	....	....	....	"
1906 Apr. 2....	....	....	....	....	194	....	....	....	....	"

1906 Apr. 9	Tap in Winnipeg	....	....	....	178	....	....	....	....	....	Smart
1906 Apr. 17	" "	....	....	....	200	....	....	....	....	....	"
1906 Apr. 19	" "	....	....	....	154	....	....	....	....	....	"
1906 Apr. 26	" "	....	....	....	249	....	....	....	....	....	"
1906 Jan. 6	" "	....	....	283	165	118	....	....	....	....	"
1906 Jan. 11		....	....	296	180	116	....	....	....	....	"
1906 Jan. 12	" "	....	....	304	186	118	....	....	....	....	"
1906 Jan. 20	" "	....	....	280	162	118	....	....	....	....	"
1906 Jan. 22	" "	....	....	294	176	118	50	....	....	....	"
1906 Jan. 27	" "	....	....	300	182	116	50	....	....	....	"

Averages and Estimates

Average	Well No. 1 unsoftened	....	242	[illegible]	368	101	74	....	..		
Average	Well No. 2 unsoftened	....	248	470	366	104	64	....	..		
Best values	Wells 1 and 2 unsoftened	....	245	480	360	120	63	....	30		
Average	Well No. 1 softened	....	236	216	96	120	35	....	..		
Average	Well No. 2 softened	....	250	315	177	128	33	....	..		
Average	Tap water, 1905	....	...	188	80	108	..	....	..		
Best value	Softened water	....	245	210	80	120	34	....	..		
Average	Well No. 3	....	202	465	348	117	59	0.30	28		
Average	Well No. 4	....	222	475	342	120	59	0.30	26		
Average	Tap water, 1906	....	...	304	186	110	..	....	..		
	Tap water, calculated analysis of mixture—										
	Softened water, 2.5 mil. gals.										
	Well No. 3, 0.5 "										
	Well No. 4, 1.0 "										
	Total, 4.0 "	....	222	307	185	122	42	0.15	..		

APPENDIX C.

TABLE 6.

Ground Water Analysis.

	Chlorine	Hardness.	Alkalinity	Total Solids	Location	Authority
A	14.4	....	....	....	Lake Winnipeg, Winnipeg Beach	C.P.R.
B	18.0	....	...	....	Stonewall, wells 100 ft and 145 ft deep	"
C	45.0	....	....	....	W. Selkirk, well 175 ft deep ...	"
D	21.0	....	....	....	E. Selkirk, well 15 ft deep......	"
E	240.0	....	....	....	Winnipeg, city wells, 45 ft deep.	"
F	12.0	....	....	....	Rosser, well................	"
G	23.0	....	....	....	Poplar Point, soakage from Assiniboine River.........	"
H	88.0	921	807	....	Portage la Prairie, well 18 ft deep	"
I	19.0	....	427	493	Crystal Springs.............	L. A. Smart
—	23.0	....	....	625	W. Selkirk (June, 1897).......	Kenrick
—	51.0	....	....	617	Stonewall	"
J	35.0	....	452	....	Poplar Springs.............	L. A. Smart
K	17.5	....	452	....	S.W.Q. Sec. 21, Tp. 12, R. 2E, well 40 ft deep.	"
L	72.5	....	424	....	William Quarry, 1.5 miles N. E. of Lillyfield	"
M	15.0	....	322	....	New City Quarry, at Stony Mountain	"
N	35.0	....	454	....	S.W.Q. Sec. 22, Tp. 12, R. 2E, well 40 ft deep........	"
—	248	420	331	....	Well No. 2, before softening....	"
O	690	889	820	....	Serial No. 1...............	"
P	206	603	366	...	" " 2...............	"
Q	118	663	514	....	" " 3, June 13-16, 1907.	"
R	302	983	790	....	" " 4...............	"
S	238	619	330	....	" " 5...............	"
T	396	649	466	....	" " 6...............	"
U	212	....	448	....	" " 7...............	"
V	26	....	576	....	" " 8...............	"
W	86	....	546	....	" " 9...............	"
X	11	....	504	....	" " 10...............	"
Y	120	620	874	....	Shoal Lake, N.W. of Winnipeg .	"

TABLE No. 7

Summary of Analyses Showing Mineral Constituents.—Red River.

Parts per Million.

Date	Locality	Total Solids	Chlorine	Total Hardness	Alkalinity	Incrustants	Magnesium	Iron	Free Carbonic Acid	Analyst
1905—February 17	Above mouth of Assiniboine			324	268	56				
" March 21	Norwood Bridge	510	77.0	254	192	62				Parker
1904—April 9		342	37 0	275	256	19	27	1.0		Whipple
1905— " 10		482		227	162	65	48			Kenrick
1907—March 24				220	165	55				
" April 16				218	154	62				
" June 3	Main St. Bridge	435	24.5	275	174	101				
1906—	St. Vital Ferry	380	30.0	208	191	17		1.5		Smart
1907—April 9	" " Depth 2ft.	224	8.5	168	86	82				"
" " "	" " " 4ft.	310	6.0	129	54	75				"
1906—September 2	" "	380	30.5	208	191	17				"
1907—June	" "	563	7.5	285	200	85				"
" April	" "	360	8.0	158	124	34	33	1.8	7.5	Whipple
" June	" "	405	27.0	231	195	36				Smart
Probable annual average			25 0	250	180	70	35		5	
" minimum			5.0	150	120	30	25		3	
" maximum			75.0	350	250	100	45		10	

TABLE 8.

Results of Bacteriological Analysis of Red River Water.

(By Dr. J. H. Leeming, City Bacteriologist.)

Date	Locality	Numbers of Bacteria per c. c.	Test for B. coli.
March 14, 1906.	Foot of Athole Ave., 80 ft from bank, 3 ft deep.	2750	X
"	At Bathing Station, 200 ft from bank, 7.5 ft deep.	2700	X
"	At Bathing Station, 200 ft from bank, 4 ft deep.	2800	X
"	South of Arnold Ave., mid-stream, depth 3 ft.	1710	X
"	South of Arnold Ave., mid-stream, depth 6 ft	1710	X
"	South of Arnold Ave., mid-stream, depth 9 ft.	1705	X
April 9, 1907.	St. Vital Ferry, depth 4 ft.	1570	X
June 8, 1907.	St. Vital Ferry, depth 4 ft.	1563	X

X indicates presence of B. coli.

TABLE 9.

Summary of Analyses Showing Mineral Constituents.—Assiniboine River.

Parts per Million.

Date	Locality	Total Solids	Chlorine	Total Hardness	Alkalinity	Incrustants	Magnesium	Iron	Free Carbonic Acid	Analyst
1905 Feb 16	....	814	....	483	353	128	....	....	....	Parker
1905 Mar. 21	....	740	32	459	346	115	52	0.5	....	Whipple
1902 Aug. 30	....	717	28	429	331	98	....	....	....	Hutton
1902 Oct. 10	....	586	25	400	....	....	....	....	....	Drown
1900 May	....	350	20	....	....	....	....	....	....	....
1905 Dec. 28	....	758	35	421	320	101	....	....	....	Smart
1903 Jan. 6	....	720	35	448	342	106	....	....	....	"
1908 Mar. 8	....	740	31	473	387	85	....	....	....	"
1908 Mar. 21	....	740	32	450	346	113	....	....	....	"
1908 April 2	....	600	24	380	256	124	....	....	....	"
1908 April 7	....	500	18	271	213	68	....	....	....	"
1908 April 10	....	444	16		190	....	....	....	....	"
1906 April 17	....	528	15	200	80	111	....	....	....	"
1906 April 19	....	304	11	186	80	108	....	....	....	"
1908 July 24	....	635	42	335	105	230	....	....	....	"
1906 Aug. 30	....	673	47	357	115	242	....	....	....	"
1903 Sept. 6	....	673	47	347	115	232	....	....	....	"
1907 April 5	....	580	19	306	290	103	....	....	....	"
1907 June 13	....	415	20	....	210	....	....	....	....	"
1905 Nov. 11	....	593	45	....	250	....	....	....	....	"
1905 April 10	....	700	....	406	328	78	....	....	....	"
1907 Mar. 23	....	....	....	395	350	45	....	....	....	"
1905 April 8	....	....	....	406	338	78	....	....	....	"
1905 April 12	....	....	....	260	157	103	....	....	....	"
1905 April 17	....	....	....	230	184	46	....	....	....	"
1905 April 26	....	....	....	250	207	43	....	....	....	"
1908 Feb. 17	....	....	27	416	294	122	....	....	....	"
Average	....	614	28	366	247	112	....	....	....	
	Probable Annual Average	....	30	375	250	125	52	0.5	....	
	" Minimum	....	10	200	100	100	50			
	" Maximum	....	50	500	350	150				

TABLE 10.

Turbidity and Color Observations, Whitemouth River, June 13 and 14, 1907.

River	Locality	Turbidity	Color	Taste
Beaver Creek, branch of Whitemouth River...	1.5 miles below Whitemouth Station, road crossing	8	125	—
Plum Creek, branch of Whitemouth River...	Road crossing, 3 miles below station.......	8	150	—
Whitemouth River.....	Bridge 3.5 miles below Whitemouth Station.	25	180	3v
Boggy River, branch of Whitemouth River...	Road crossing, 9 miles below Whitemouth Station	8	150	—
Gutter, along road	In muskeg..........	2	800	3v
Whitemouth River.....	At mouth, *i.e.* where it enters Winnipeg Riv.	20	175	3v
Winnipeg River	Above Whitemouth Riv.	5	50	3v

TABLE 11.

Analysis of Sample of Winnipeg River Water above Whitemouth River. Collected June 13, 1907.

	Parts per Million.
Turbidity	12
Color	45
Odor	Very faint vegetable.
Total solids	170
Loss on ignition	26
Fixed solids	144
Hardness	39
Iron	0.6
Chlorine	0.7

TABLE 12.

Analysis—Lake of the Woods and Shoal Lake.

(By L. A. Smart.)

Parts per Million.

Date, 1907	Chlorine	Hardness	—
June 15	2.5	32*	Lake of the Woods, near intake of Kenora waterworks
" 15	2	38	Lake of the Woods, Ash Rapids
" 15	2.5	50	Shoal Lake, north of Martinique Island
" 15	2.0	44*	Indian Bay, Provincial boundary line
" 15	2.0	47	Indian Bay, near flag, at surface
" 15	2.0	42*	Indian Bay, near flag, depth 20 feet

* Approximate value only, as an inaccuracy was introduced by reason of the use of bottles which proved to be of a quality which affected the water.

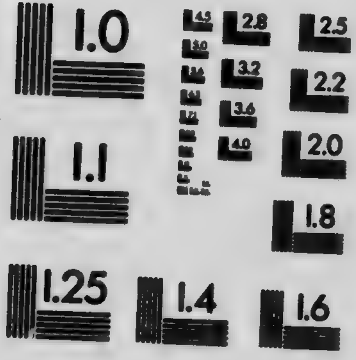
TABLE 13.

Color Observations—Lake of the Woods, June 15, 1907.

Source	Locality	Color
Lake of the Woods	Near intake of Kenora waterworks	35
" "	Second channel, 5 miles from Kenora	35
" "	Ptarmigan Bay, south of Corkscrew Island	37
" "	Ash Bay	20
" "	Ash Rapids	20
Shoal Lake	Shoal Lake Narrows	12
" "	North of Dominique Island	5
" "	Opposite mouth of Snowshoe Bay, north of Indian Mission School	20
" "	Indian Bay Narrows, west of Long Island	10
Indian Bay	Indian Bay Narrows, north-west end	18
" "	About 0.5 mile from mouth of Falcon River	65
" "	About 0.8 mile from mouth of Falcon River	130
" "	In cove, north-east of Falcon River	60
Falcon River	At mouth	160
" "	Above Snake outlet	180
Snake Lake	About the middle	140

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc
1653 East Main Street
[illegible]er, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

TABLE 14.

Color Observations. Indian Bay, Shoal Lake, June 16, 1907.
Samples collected at one-minute intervals from the Provincial boundary line to the mouth of Falcon River.

Time	Depth in Feet	Color	Remarks
8:55 a.m.	20	20	Ontario-Manitoba boundary.
8:56 a.m.	19	22	
8:57 a.m.	19	22	
8:58 a.m.	19.5	23	
8:59 a.m.	20.5	23	
9:00 a.m.	20	23	Water has agreeable taste.
9:01 a.m.	20.5	24	
9:02 a.m.	21	24	
9:03 a.m.	20	25	
9:04 a.m.	20	26	
9:05 a.m.	20	27	
9:06 a.m.	20	27	
9:07 a.m.	20	27	
9:08 a.m.	19.5	27	
9:09 a.m.	19.5	28	
9:10 a.m.	19	30	
9:11 a.m.	20	31	
9:12 a.m.	19.5	32	
9:13 a.m.	19	34	
9:14 a.m.	18.5	34	
9:15 a.m.	17	35	
9:16 a.m.	17.5	35	
9:17 a.m.	17.5	35	
9:18 a.m.	18	35	
9:19 a.m.	18	35	
9:20 a.m.	18	35	
9:21 a.m.	16	35	
9:22 a.m.	15	36	On line between two small islands.
9:23 a.m.	14	36	
9:24 a.m.	14	36	
9:25 a.m.	14	36	
9:26 a.m.	14.5	36	Slight vegetable taste.
9:27 a.m.	14.5	37	
9:28 a.m.	14.5	39	
9:29 a.m.	14	42	
9:30 a.m.	12.5	44	About opposite the "point."
9:31 a.m.	10	50	
9:32 a.m.	8	55	
9:33 a.m.	6.5	90	Distinct vegetable taste.
9:34 a.m.	5	180	400 ft. from shore. Opposite mouth of Falcon River.

At the time these observations were taken, the wind was blowing in an easterly direction, that is, towards the mouth of the Falcon River. During the night previous, however, the wind had been blowing from the west.

TABLE 15.

Analysis of a Sample from Lake of the Woods at Kenora, collected June, 1907.

(By M. C. Whipple.)

	Parts per Million
Turbidity	5
Color	37
Odor	2v
Total solids	99
Loss on ignition	36
Fixed solids	63
Iron	0.25
Nitrogen as nitrates	0
Nitrogen as nitrates	0.002
Chlorine	0.7
Hardness	42
Alkalinity	42
Incrustants	0
Free carbonic acid	4.0

TABLE 16.

Analysis of a Sample of Water from Little Shoal Lake (North-West of City of Winnipeg), Collected June, 1907.

(By M. C. Whipple.)

	Parts per Million.
Turbidity	105
Color	53
Odor	3v
Total solids	1621
Hardness	620
Alkalinity	874
Alkalinity due to alkaline carbonates	254
Chlorine	120
Magnesium	79
Iron	0.6
Free carbonic acid	0.
Nitrogen as nitrates	0.

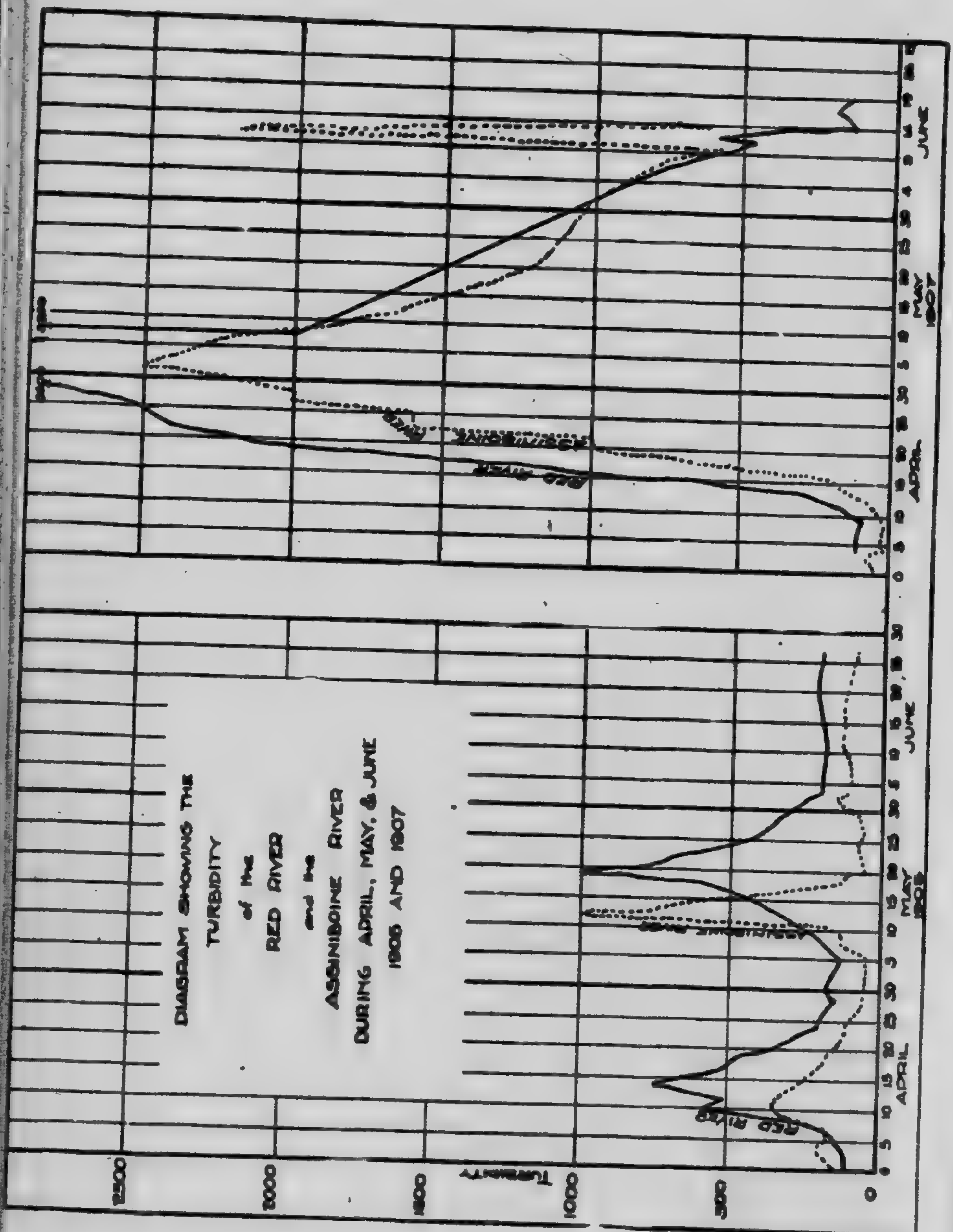


DIAGRAM SHOWING THE
TURBIDITY
of the
RED RIVER
and the
ASSINIBOINE RIVER
DURING APRIL, MAY, & JUNE
1906 AND 1907
TURBIDITY
RED RIVER
ASSINIBOINE RIVER
APRIL
MAY
JUNE
1907
0
500
1000
1500
2000
2500

APPENDIX D.

Estimates

---

1. Cost of Construction.

2. Annual Cost of Operation and Maintenance.

NOTES.—In all the following estimates the headings have been abbreviated to save space; in these the intake includes the intake pipes with their supports, protective cribs and masonry, gate-houses with screens and gates.

The pipe lines include excavation, clearing and grubbing, gates, air valves, stand pipes, blow-off, manholes and extra work at river crossings, etc.

The filters include all necessary devices for coagulation, all apparatus for washing the filters, the buildings and store houses, and chemical and bacteriological laboratories.

The pumping stations include the pumps with their foundations, boilers, steam and water piping and connections, all auxiliary machinery and apparatus, and the buildings and stacks.

The reservoir, settling basins and coagulation basins are all covered and provided with the necessary gates, baffles, connections and other appurtenances.

Estimate No. 1.

Supply from Red River.

Water Softened and Filtered.

Water pumped from Red River at St. Norbert to settling basins, then filtered and softened and pumped with low duty pumps to a filtered-water reservoir at the McPhillips Street station in Winnipeg, and thence pumped into the street mains with high duty pumping engines. Four 48-inch steel pipe lines, one line to be laid with each new installation of 12,000,000 gallons average daily capacity.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land	$10,000	$10,000	$10,000	$10,000
Intake	50,000	50,000	50,000	50,000
Low lift pumping station at St. Norbert	75,000	95,000	155,000	200,000
Settling basins	360,000	360,000	720,000	720,000
Coagulating basins	18,000	18,000	36,000	36,000
Filters	275,000	550,000	825,000	1,100,000
Intermediate low lift pumping station	75,000	95,000	155,000	200,000
Pipe lines	562,000	1,094,000	1,656,000	2,188,000
Pure water reservoir	90,000	90,000	180,000	270,000
Pumping station in Winnipeg at the McPhillips Street location	370,000	645,000	920,000	1,200,000
	1,885,000	3,007,000	4,707,000	5,974,000
15 %	283,000	451,000	706,000	896,000
Totals	2,168,000	3,458,000	5,413,000	6,870,000

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$ 98,000	$156,000	$244,000	$309,000
Depreciation	18,000	32,000	49,000	68,000
Maintenance of pipes, etc.	1,000	1,000	2,000	2,000
Pumping, low lift	14,000	28,000	42,000	56,000
Pumping, intermediate	11,000	21,000	32,000	42,000
Filtering	44,000	88,000	131,000	175,000
Softening	123,000	245,000	368,000	491,000
High duty pumping	50,000	100,000	150,000	200,000
Totals	$359,000	$671,000	$1,018,000	$1,343,000

Estimate No. 2.

Supply from Red River.

Water Filtered, but Not Softened.—Data same as for Estimate 1.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$ 10,000	$ 10,000	$ 10,000	$ 10,000
Intake	50,000	50,000	50,000	50,000
Low lift pumping station at St. Norbert	75,000	95,000	155,000	200,000
Coagulating basins	18,000	18,000	36,000	36,000
Settling basins	360,000	360,000	720,000	720,000
Filters	250,000	500,000	750,000	1,000,000
Intermediate low lift pumps at St. Norbert	75,000	95,000	155,000	200,000
Pipe lines	562,000	1,094,000	1,656,000	2,188,000
Pure water reservoir	90,000	90,000	180,000	270,000
High duty pumps in Winnipeg	370,000	645,000	920,000	1,200,000
	$1,860,000	$2,957,000	$4,632,000	$5,874,000
Add 15 per cent	279,000	443,000	695,000	881,000
Totals	$2,139,000	$3,400,000	$5,327,000	$6,755,000

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$96,000	$153,000	$240,000	$304,000
Depreciation	18,000	32,000	49,000	68,000
Maintenance of pipes, etc	1,000	1,000	2,000	2,000
Pumping, low lift	14,000	28,000	42,000	56,000
Intermediate low lift	11,000	21,000	32,000	42,000
Filtering	44,000	88,000	131,000	175,000
Pumping in Winnipeg	50,000	100,000	150,000	200,000
Totals	$234,000	$423,000	$646,000	$847,000

Estimate No. 3.

Filtered Supply from Winnipeg River.

Wood stave pipe, three lines, with capacity of 23,000,000 gallons daily each; one line to be built immediately, the second when the average daily consumption reaches 17,000,000 gallons, and the third when it reaches 33,000,000 gallons.

Each pipe line consists of three sections as follows:

7.3 miles of 45-inch pipe.
5.0 miles of 54-inch pipe.
43.5 miles of 48-inch pipe.

Intake works consist of an 8-foot dam across river, intake pipe, well, screens and gates.

Pumping station at Winnipeg River to be equipped with triple expansion condensing crank-and-fly-wheel steam-pumping engines, boilers, condensers and auxiliary machinery.

Pipe lines to be provided with gate valves, standpipes, air valves, manholes and blow-offs.

Equipment at McPhillips Street station to consist of coagulating basin, rapid filters, filtered water reservoir and high duty pumping engines of the triple expansion, condensing, crank-and-fly-wheel type, to pump the filtered water into the street mains.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$18,000	$18,000	$18,000	$18,000
Intake works	150,000	150,000	150,000	150,000
Pumping station at Winnipeg River	325,000	465,000	740,000	1,015,000
Pipe lines	1,737,000	3,399,000	5,111,000	5,111,000
Coagulating basins	65,000	65,000	130,000	130,000
Filters	250,000	500,000	750,000	1,000,000
Filtered water reservoir	270,000	270,000	350,000	350,000
Winnipeg pumping station	370,000	645,000	920,000	1,200,000
Keepers' houses	12,000	12,000	12,000	12,000
Telephone lines	11,000	11,000	11,000	11,000
Tramway	150,000	150,000	150,000	150,000
	$3,358,000	$5,685,000	$8,342,000	$9,147,000
Add 15 %	504,000	853,000	1,251,000	1,372,000
Totals	$3,862,000	$6,538,000	$9,593,000	$10,519,000

Estimate No. 3—(*Continued*).

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$174,000	$294,000	$432,000	$473,000
Depreciation	33,000	59,000	90,000	106,000
Pumping	80,000	160,000	240,000	320,000
Filtering	44,000	88,000	131,000	175,000
Maintenance of pipes, keepers' wages, etc.	12,000	19,000	29,000	29,000
Totals	$343,000	$620,000	$922,000	$1,103,000

Estimate No. 4.

Filtered Supply from Winnipeg River.

Three lines of steel pipe, each in three sections, as follows :—

7.8 miles of 50-inch pipe.
5.0 miles of 60-inch pipe.
48.5 miles of 54-inch pipe.

Other data same as Estimate No. 3.

COST OF CONSTRUCTION.

Items.	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$ 18,000	$ 18,000	$ 18,000	$ 18,000
Intake works	150,000	150,000	150,000	150,000
Winnipeg River pumping station	325,000	465,000	740,000	1,015,000
Pipe lines....................	3,640,000	7,205,000	10,820 000	10,820,000
Coagulating basin	65,000	65,000	130,000	130,000
Filters	250,000	500,000	750,000	1,000,000
Reservoir	270,000	270,000	350,000	350,000
Pumping station in Winnipeg ..	370,000	645,000	920,000	1,200,000
Keepers' houses	12,000	12,000	12,000	12,000
Telephone lines	11,000	11,000	11,000	11,000
Tramway	150,000	150,000	150,000	150,000
	$5,261,000	$9,491,000	$14,051,000	$14,856,000
15 per cent............	789,000	1,424,000	2,108,000	2,228,000
Totals	$6,050,000	$10,915,000	$16,159,000	$17,084,000

ANNUAL COST OF OPERATION.

Items.	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$272,000	$491,000	$727,000	$769,000
Depreciation	60,000	112,000	164,000	180,000
Pumping at Winnipeg River ...	30,000	60,000	91,000	121,000
Filtering.....................	44,000	88,000	131,000	175,000
Maintenance of pipes and keepers' wages	12,000	19,000	29,000	29,000
Pumping in Winnipeg	50,000	100,000	150,000	200,000
Totals	$468,000	$870,000	$1,292,000	$1,471,000

Estimate No. 5.

Filtered Supply from Indian Bay, Shoal Lake.

Wood Stave Pipes.

Water delivered by gravity to a reservoir in Winnipeg and after filtration pumped into street mains.

Three pipe lines with capacity of 23,000,000 gallons each; one line to be built immediately, the second when the average daily consumption reaches 17,000,000 gallons, and the third when it reaches 33,000,000 gallons.

Each pipe line consists of three sections as follows:

22.6 miles of 64-inch pipe.
27.0 miles of 54-inch pipe.
43.0 miles of 48-inch pipe.

Intake works consist of submerged pipe extending out one and one-half miles into Indian Bay, with protective crib at end and gate-house with screen gates at shore near mouth of Falcon River.

Pipe lines provided with gates, air-valves, standpipes, blow-offs and manholes.

Equipment at McPhillips Street station to consist of coagulating basins, rapid filters, filtered-water reservoir and high-duty pumping engines of the triple expansion, condensing, crank-and-fly-wheel type, to pump the filtered water into the street mains.

COST OF CONSTRUCTION

Items	For an Average Daily Supply of 12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Intake works	65,000	65,000	95,000	95,000
Pipe lines	2,5[illegible]9,000	5,187,000	7,907,000	7,907,000
Coagulating basins	65,000	65,000	130,000	130,000
Filters	250,000	500,000	750,000	1,000,000
Filtered water reservoir	270,000	270,000	350,000	350,000
Pumping station in Winnipeg	370,000	645,000	920,000	1,200,000
Keepers' houses	20,000	20,000	20,000	20,000
Telephone lines	18,000	18,000	18,000	18,000
	$3,672,000	$6,795,000	$10,215,000	$10,745,000
Add 15%	551,000	1,019,000	1,532,000	1,612,000
Totals	$4,223,000	$7,814,000	$11,747,000	$12,357,000

ANNUAL COST OF OPERATION AND MAINTENANCE

Items	For an Average Daily Supply of 12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$190,000	$352,000	$529,000	$556,000
Depreciation	33,000	64,000	94,000	104,000
Filtering	44,000	88,000	131,000	175,000
Pumping	50,000	100,000	150,000	200,000
Maintenance of pipes, keepers' wages, etc.	21,000	39,000	63,000	63,000
Totals	$338,000	$643,000	[illegible]967,000	$1,098,000

Estimate No. 6.

Supply from Indian Bay, Shoal Lake.

Steel Pipe Lines.

Three lines of steel pipes, in three sections each, as follows :—

22.6 miles of 70-inch pipe.
37.0 miles of 57-inch pipe.
43.0 miles of 52-inch pipe.

All other data same as in Estimate No. 5.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$25,000	$25,000	$25,000	$25,000
Intake works	65,000	65,000	95,000	95,000
Pipe lines	6,725,000	13,445,000	20,125,000	20,125,000
Coagulating basins	65,000	65,000	130,000	130,000
Filters	250,000	500,000	750,000	1,000,000
Filtered water reservoir	270,000	270,000	350,000	350,000
Pumping station in Winnipeg	370,000	645,000	920,000	1,200,000
Keepers' houses	20,000	20,000	20,000	20,000
Telephone lines	18,000	18,000	18,000	18,000
	$7,808,000	$15,053,000	$22,433,000	$22,963,000
Add 15 %	1,171,000	2,258,000	3,364,000	3,444,000
Totals	$8,979,000	$17,311,000	$25,798,000	$26,407,000

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$404,000	$779,000	$1,161,000	$1,188,000
Depreciation	85,000	168,000	249,000	260,000
Filtration	44,000	88,000	131,000	175,000
Maintenance of pipes and keepers' wages	21,000	39,000	63,000	63,000
Pumping in Winnipeg	50,000	100,000	150,000	200,000
Totals	$604,000	$1,174,000	$1,754,000	$1,886,000

Estimate No. 7

Supply from Indian Bay, Shoal Lake.

Filtered Gravity Supply. No Pumping. Wood Stave and Steel Pipe Lines.

Two lines of pipe, as follows: first line, 22.6 miles of 68-inch, 40 miles of 72-inch wood stave, and 30 miles of 84-inch steel pipes. Second line, 22.6 miles of 74-inch, 40 miles of 72-inch wood stave, and 30 miles of 84-inch steel pipes.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Intake	95,000	95,000	95,000	95,000
Pipe lines	6,403,000	12,798,000	12,798,000	12,798,000
Coagulating basins	68,000	65,000	130,000	130,000
Filters	250,000	500,000	750,000	1,000,000
Filtered water reservoir	270,000	270,000	350,000	350,000
Keepers' houses	20,000	20,000	20,000	20,000
Telephone lines	18,000	18,000	18,000	18,000
	$7,146,000	$13,791,000	$14,186,000	$14,436,000
Add 15%	1,072,000	2,068,000	2,128,000	2,165,000
Totals	$8,218,000	$15,859,000	$16,314,000	$16,601,000

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$370,000	$714,000	$ 734,000	$ 747,000
Depreciation	71,000	140,000	143,000	146,000
Filtration	44,000	88,000	131,000	175,000
Maintenance of pipes, keepers' wages, etc.	21,000	40,000	40,000	40,000
Totals	$506,000	$982,000	$1,048,000	$1,108,000

Estimate No. 8.

Supply from Indian Bay, Shoal Lake.

Filtered Gravity Supply. No Pumping. Steel Pipe Lines.

Two lines of steel pipe, as follows: First line, 22.6 miles of 78-inch and 70 miles of 84-inch pipe. Second line, 92.6 miles of 84-inch pipe.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$ 25,000	$ 25,000	$ 25 000	$ 25,000
Intake works	95,000	95,000	95,000	95,000
Pipe lines	10,243,000	20,711,000	20,711,000	20,711,000
Coagulating basin	65,000	65,000	65,000	65,000
Filters	250,000	500,000	750,000	1,000,000
Filtered water reservoir	270,000	270,000	350,000	350,000
Keepers' houses	20,000	20,000	20,000	20,000
Telephone lines	18,000	18,000	18,000	18,000
	10,986,000	21,704,000	22,034,000	22,284,000
Add 15 %	1,648,000	3,256,000	3,305,000	3,343,000
Totals	$12,634,000	$24,960,000	$25,339,000	$25,627,000

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$568,000	$1,123,000	$1,140,000	$1,153,000
Depreciation	121,000	242,000	246,000	249,000
Filtration	44,000	88,000	131,000	175,000
Maintenance of pipes and keepers' wages	21,000	40,000	40,000	40,000
Totals	$754,000	$1,493,000	$1,557,000	$1,617,000

Estimate No. 9.

Unfiltered Supply from Shoal Lake.

Wood Stave Pipe Lines.

Water delivered by gravity into reservoir in Winnipeg and pumped thence into street mains.

Intake extended through Indian Bay to open water of Shoal Lake.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$25,000	$25,000	$25,000	$25,000
Intake	445,000	445,000	885,000	8-5,000
Pipe lines	2,839,000	5,693,000	8,547,000	8,547,000
Reservoir in Winnipeg	270,000	270,000	350,000	350,000
Pumping station in Winnipeg	370,000	645,000	920,000	1,200,000
Keepers' houses	20,000	20,000	20,000	20,000
Telephone lines	18,000	18,000	18,000	18,000
	$3,987,000	$7.116,000	$10,735,000	$11,015,000
Add 15%	598,000	1,067,000	1,610,000	1,653,000
Totals	$4.585,000	$8,183,000	$12,345,000	$12,667,000

ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$206,000	$368,000	$556,000	$570,000
Depreciation	33,000	61,000	90 000	97,000
Maintenance of pipe lines, keepers' wages, etc.	21,000	39,000	63,000	63,000
Pumping in Winnipeg	50,000	100,000	150.000	200,000
Totals	$310,000	$568,000	$859,000	$930,000

Estimate No. 10.

Unfiltered Supply from Shoal Lake.

Water delivered by gravity into reservoir in Winnipeg and pumped thence into street mains.

Intake extended through Indian Bay to open water of Shoal Lake.

COST OF CONSTRUCTION.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Land and right-of-way	$25,000	$25,000	$25,000	$25,000
Intake	445,000	445,000	855,000	855,000
Pipe lines	6,835,000	13,665,000	20,505,000	20,505 000
Reservoir in Winnipeg	270.000	270,000	350,000	350,000
Pumping station in Winnipeg	370,000	645,000	920,000	1,200,000
Keepers' houses	20,000	20,000	20,000	20,000
Telephone lines	18,000	18,000	18,000	18,000
	$7,983,000	$15,088,000	$22,693,000	$22,973,000
15 %	1,197,000	2,263,000	3,404,000	3,446,000
Totals	$9,180,000	$17,351,000	$26,097,000	$26,419,000

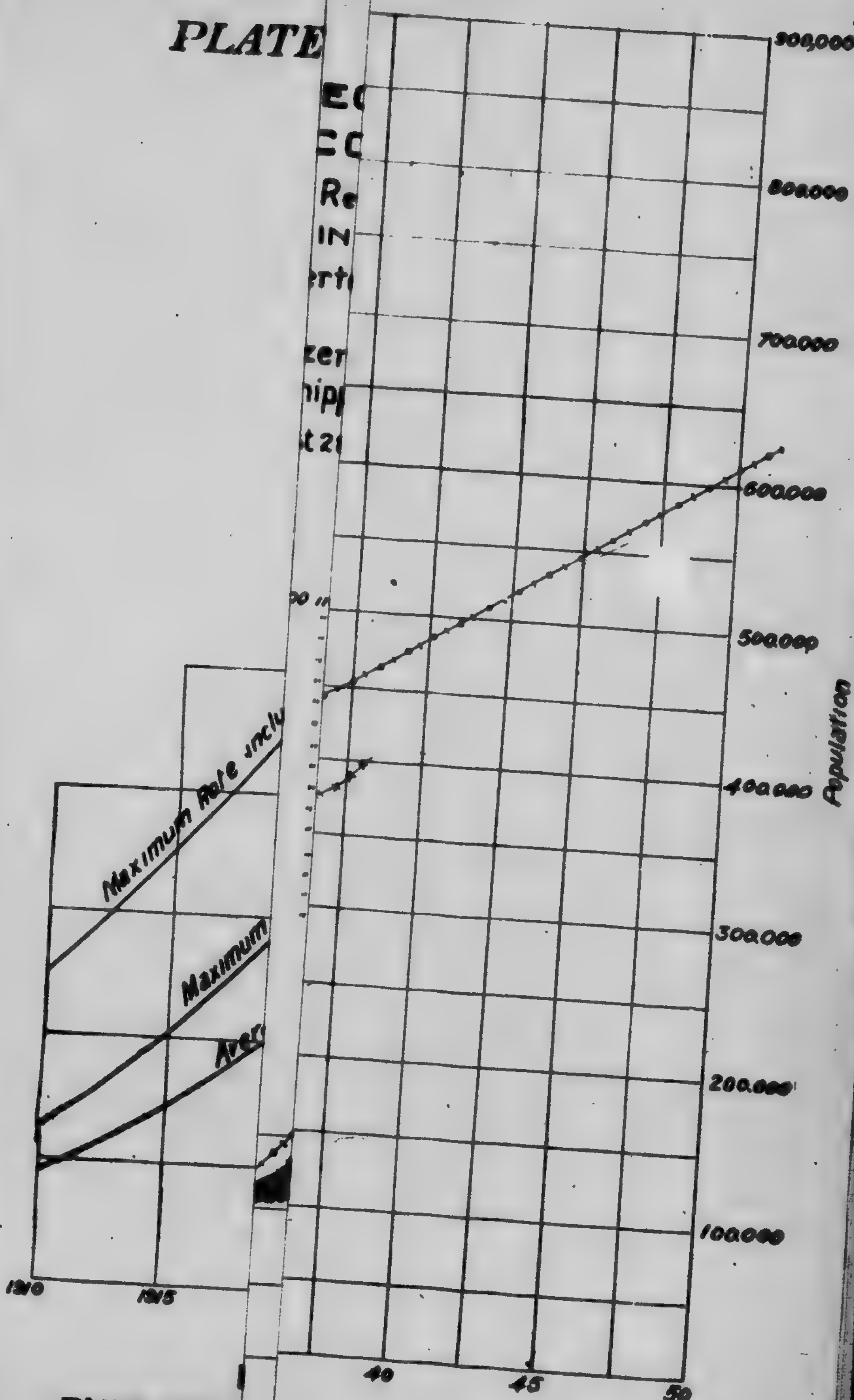
ANNUAL COST OF OPERATION AND MAINTENANCE.

Items	For an Average Daily Supply of			
	12,000,000 gallons	24,000,000 gallons	36,000,000 gallons	48,000,000 gallons
Interest	$413,000	$781,000	$1,174,000	$1,188,000
Depreciation	85,000	165,000	246,000	253,000
Maintenance of pipe lines, keepers' houses, etc.	21,000	39,000	63,000	63,000
Pumping in Winnipeg	50,000	100,000	150,000	200,000
Totals	$569,000	$1,085,000	$1,633,000	$1,704,000

PLATE

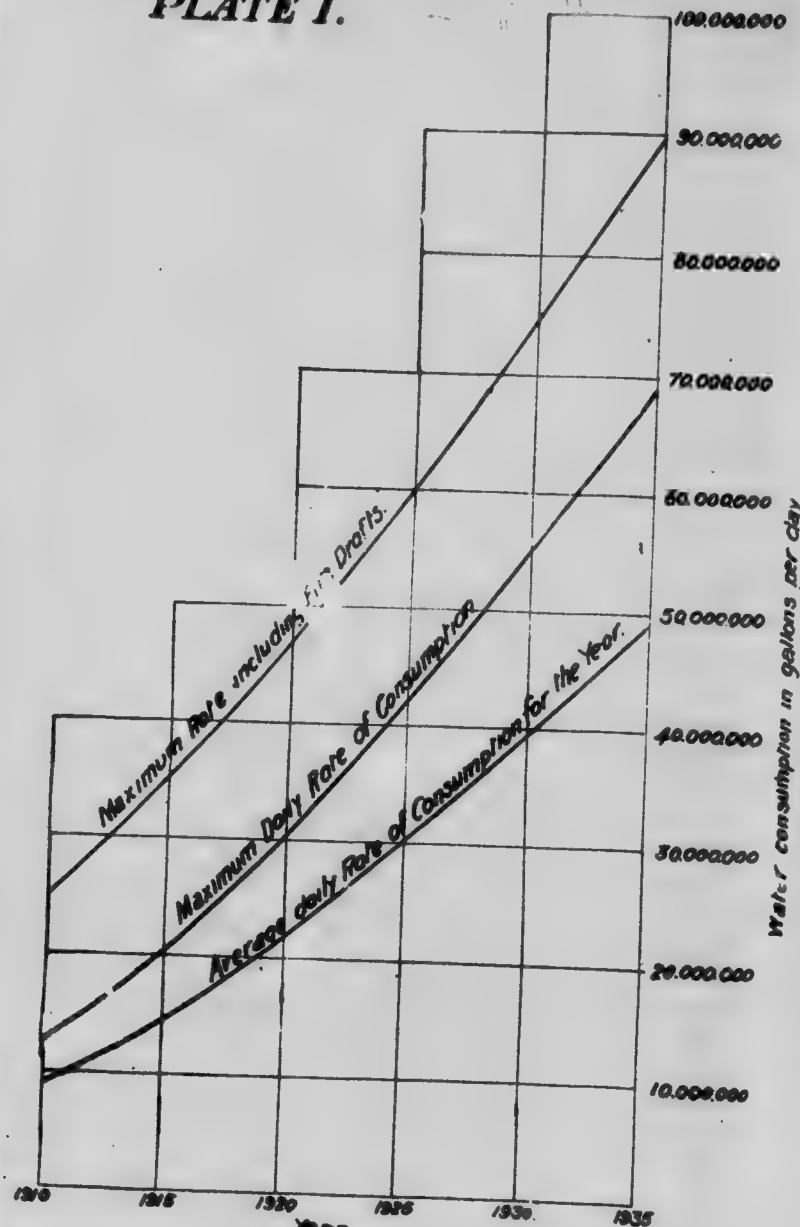
EC
CO
Re
IN
ert

zer
hipp
t 2



FUTURE V
I

PLATE I.



ESTIMATED
FUTURE WATER CONSUMPTION
IN WINNIPEG.

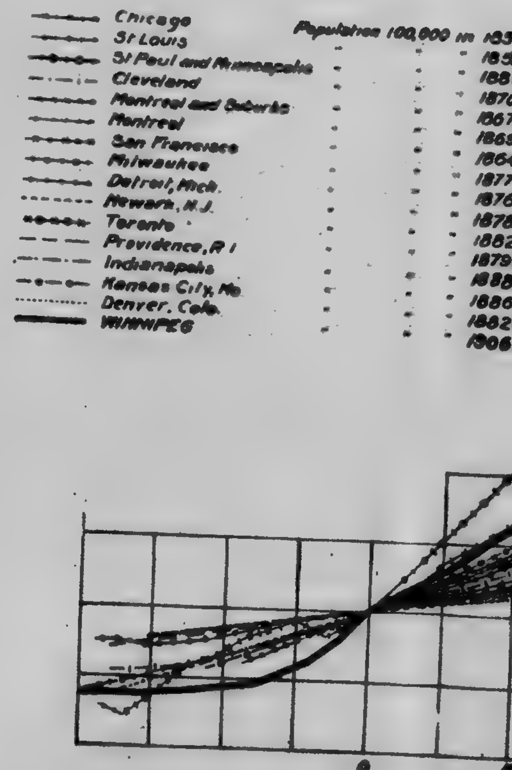
FIG. I.

WINNIPEG
WATER SUPPLY CO

To Accompany Rep
BOARD OF CONSULTING

James H. Fuertes
R. S. Lea.
J. E. Schwitzer.
George C. Whipple

August 28, 19



IPEG

Y COMMISSION.

ny Report of

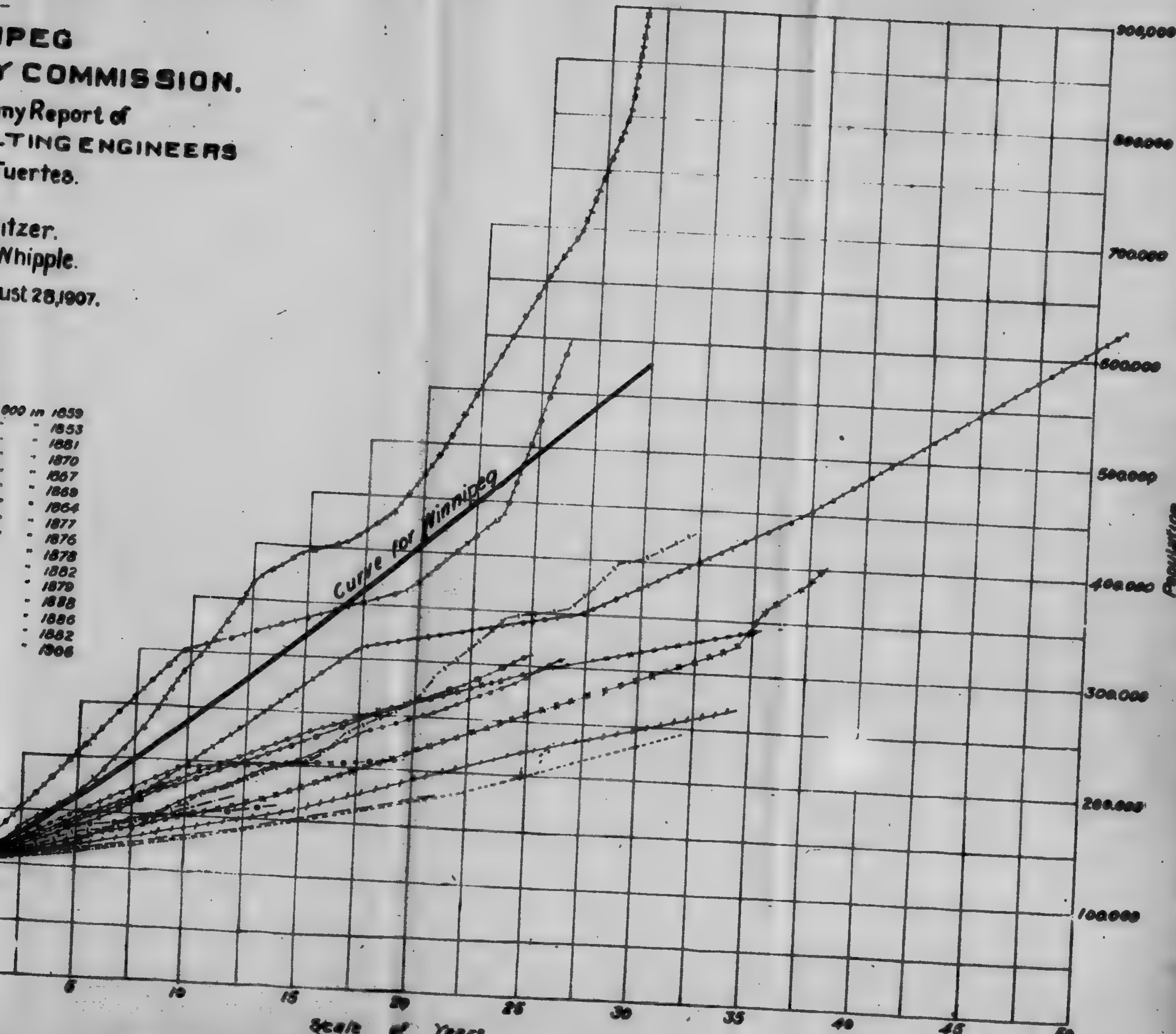
LTING ENGINEERS

Tuertes.

itzer.

Whipple.

ust 28,1907.



ESTIMATED FUTURE POPULATIONS OF WINNIPEG.

FIG. 2.

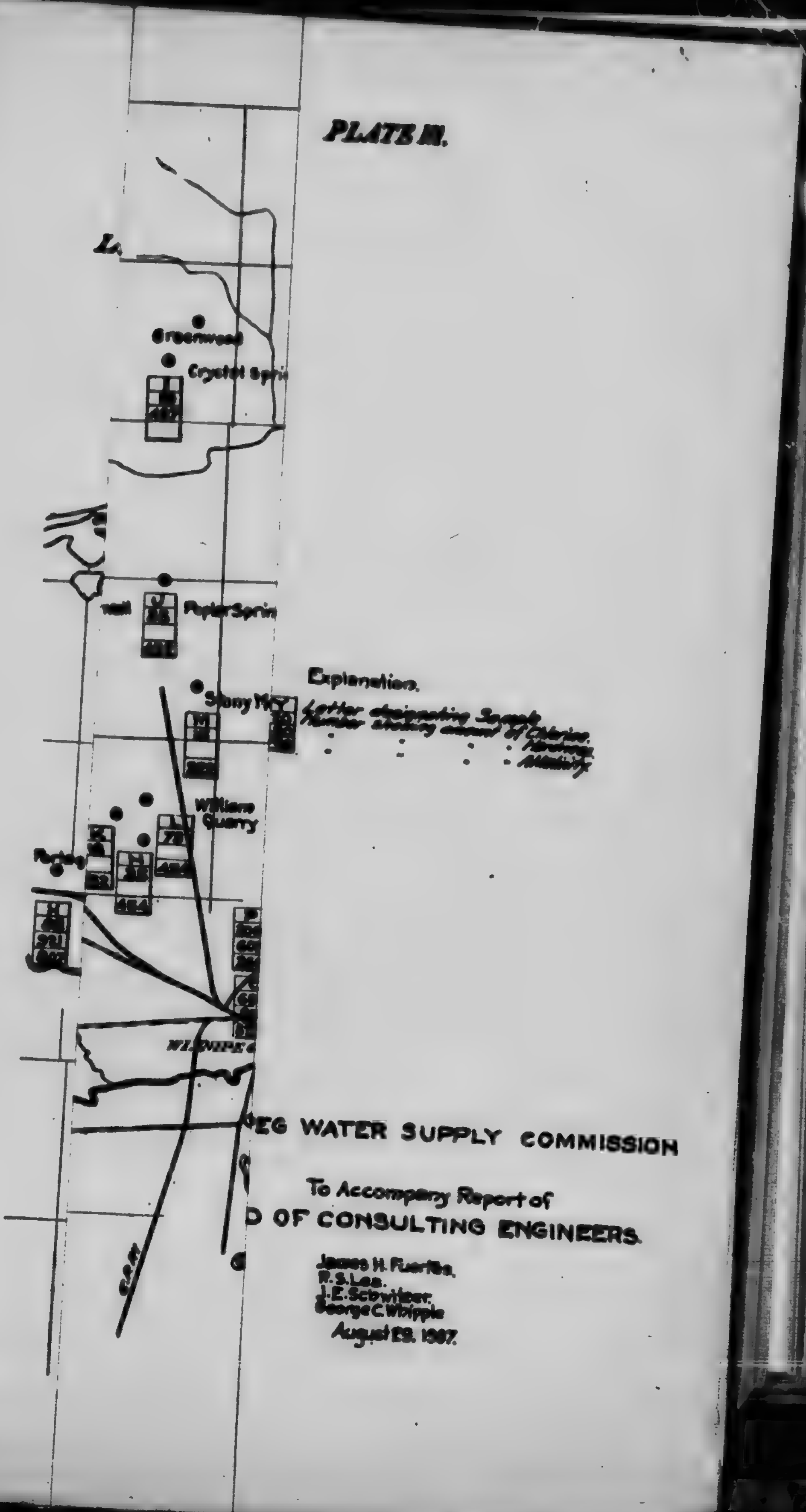

N.
ERIOR
ERSHED.
NNIPEG.

PLATE II.

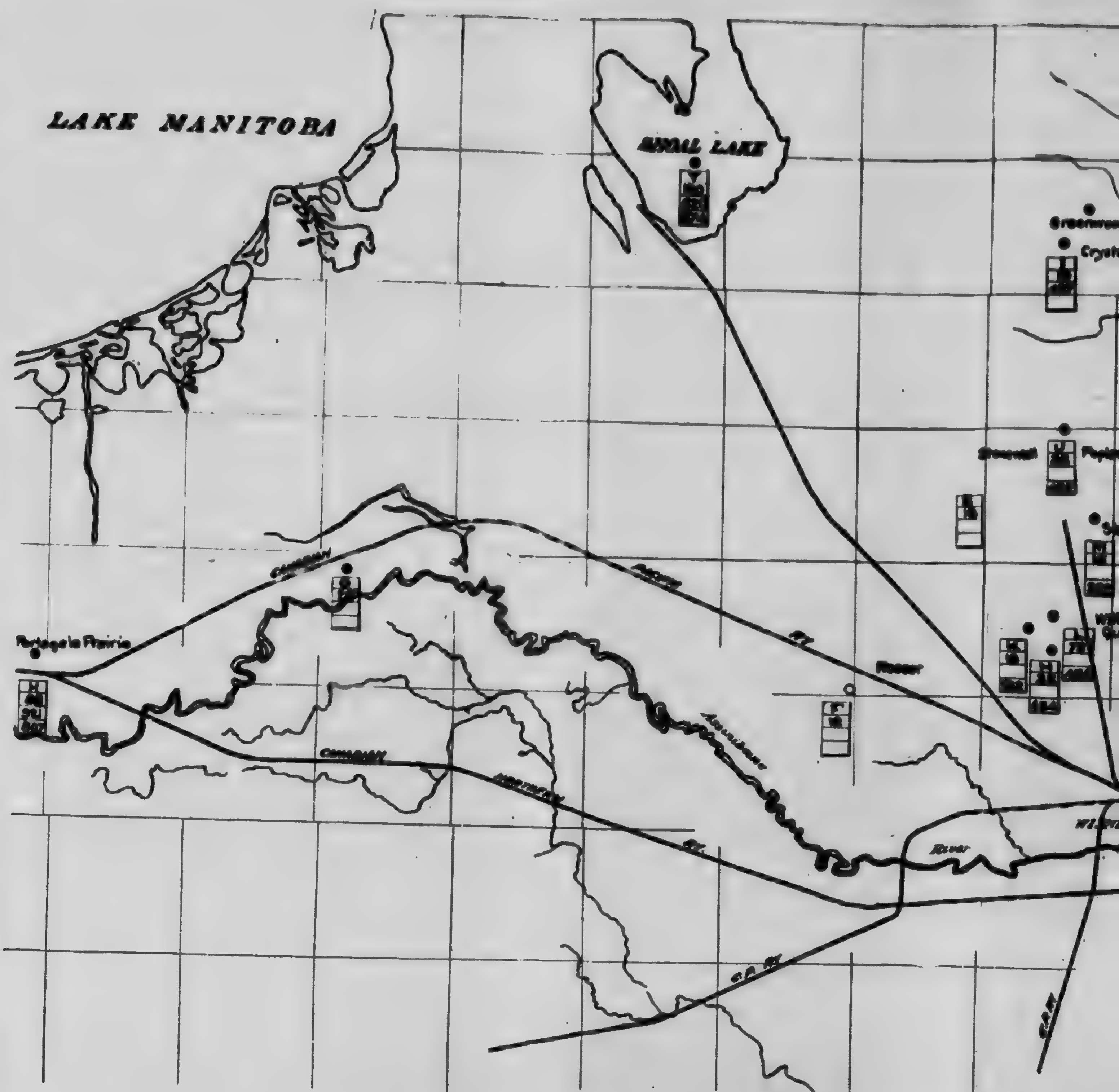
ASSINIBOINE RIVER WATERSHED
INTERNATIONAL BOUNDARY LINE
RED RIVER WATERSHED

WINNIPEG WATER SUPPLY COMMISSION.
To Accompany Report of
BOARD OF CONSULTING ENGINEERS.
James H. Fuertes.
R.S. Lea.
J.E. Schwitzer.
George C. Whipple.
August 29, 1907.
AREA.
WATERSHED.
SHOAL LAKE WATERSHED
WINNIPEG RIVER WATERSHED
LAKE OF THE WOODS WATERSHED
LAKE SUPERIOR
MAP OF DRAINAGE AREAS
AVAILABLE FOR WATER SUPPLY OF WINNIPEG.

PLATE III.

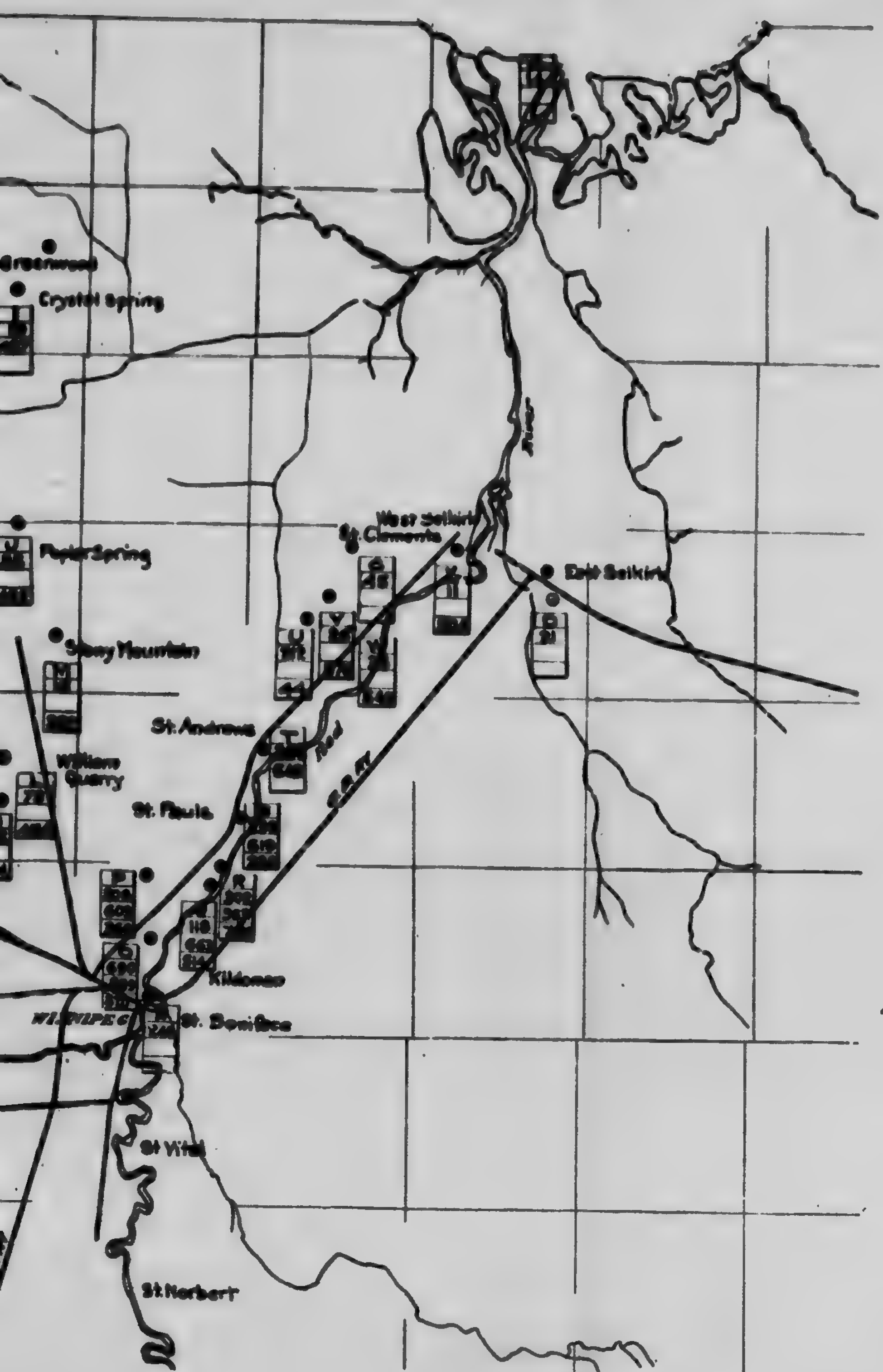


Greenwood
Crystal Sprin
Poplar Sprin
Williams Quarry
Explanation.
EG WATER SUPPLY COMMISSION
To Accompany Report of
D OF CONSULTING ENGINEERS.
James H. Fuertes,
R. S. Lea,
J. E. Schwitzer,
George C. Whipple
August 29, 1907.



MAP SHOWING AMOUNT OF CHLORINE, HARDNESS AND ALKALINITY IN THE GROUND WATER IN THE

PLATE III.



Explanation.

Letter designating Sample.
Number showing amount of Chlorine.
" " " Hardness.
" " " Alkalinity.

WINNIPEG WATER SUPPLY COMMISSION

To Accompany Report of

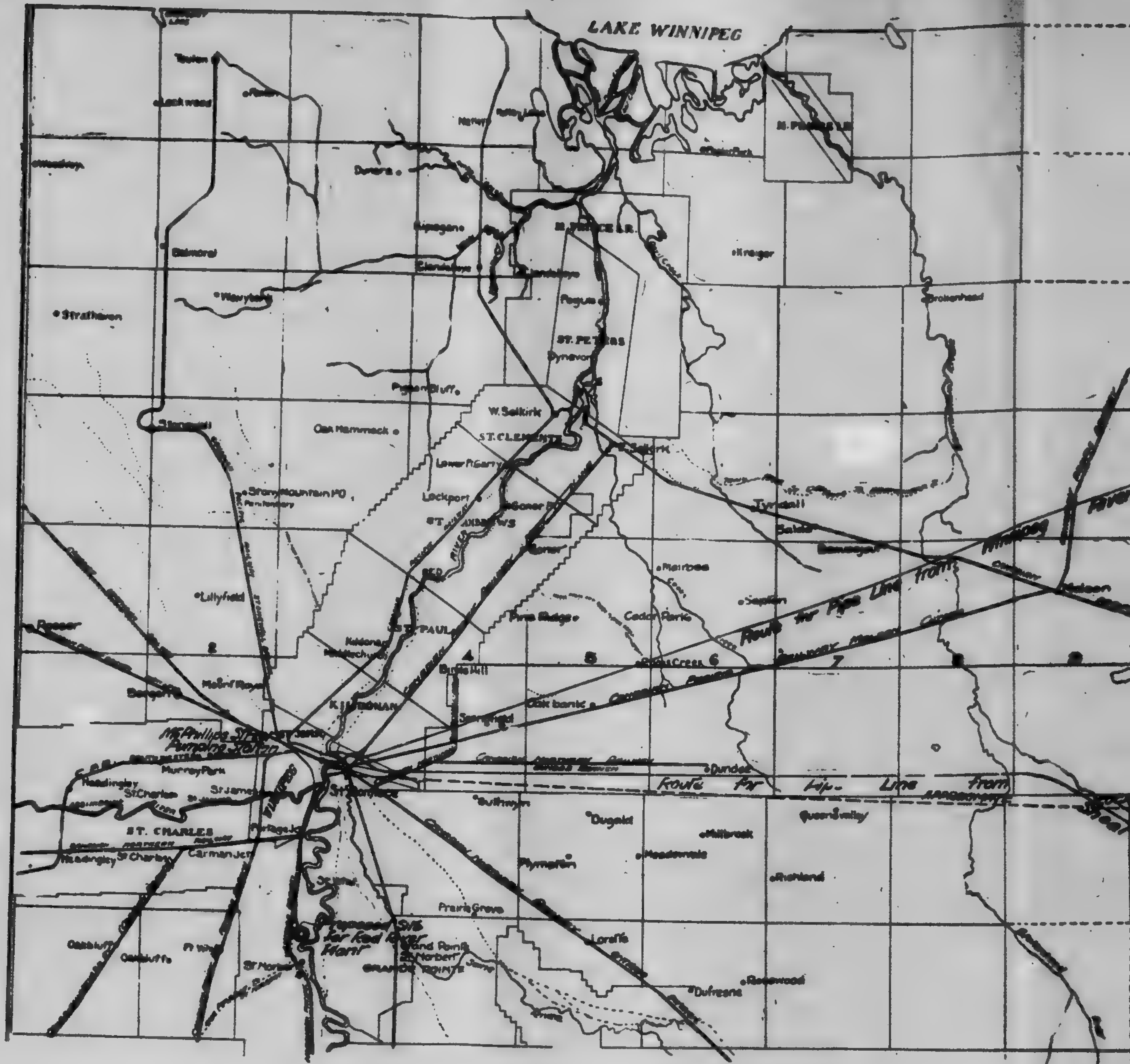
BOARD OF CONSULTING ENGINEERS.

James H. Fuertes.
R. S. Lea.
J. E. Schwitzer.
George C. Whipple.

August 29. 1907.

PLATE IV.

River
Molson
17
Cross Lake
Ingolf.
FALCON LAKE
INDIAN BAY
PES
COMMISSION
Report of
TING ENGINEER
ertes.
zer.
hipple.
EAST SHOAL LAKE



GENERAL PLAN
SHOWING ROUTES FOR PIPE LINES
FROM WINNIPEG RIVER AND SHOAL LAKE.
ALSO PROPOSED SITE FOR RED RIVER PLANT

Scale 3 Miles = 1 Inch.

WINNIPEG
WATER SUPPLY COMMISS

To Accompany Report of
BOARD OF CONSULTING ENGINE

James H. Fuertes.
R. S. Lea.
J. E. Schwitzer.
George C. Whipple.


PLATE IV.
Site for Intake and Pumping Station
Whitemouth
Darwin
Telford
Ingolf
INDIAN BAY
EAST SHOAL LAKE
G.T.P. RY
MMISSION.
ENGINEERS

PLA

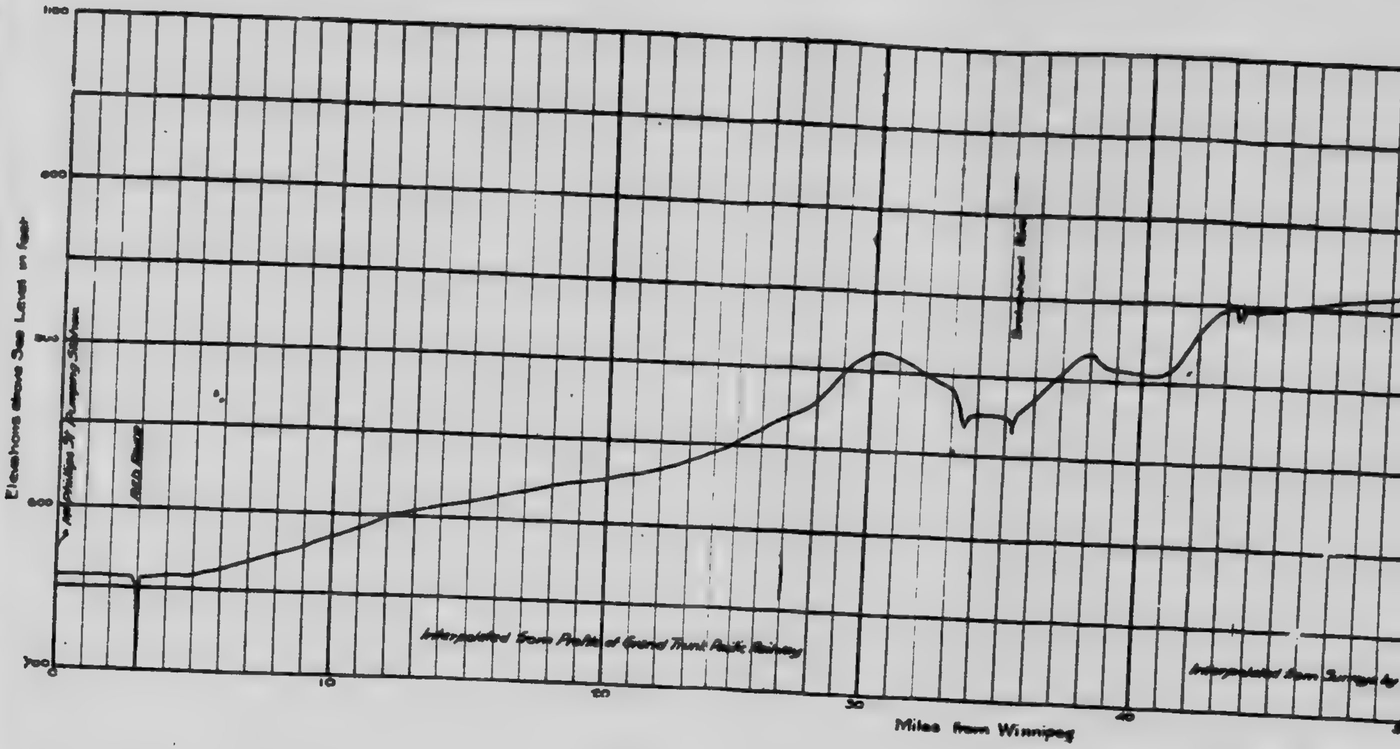
FROM SHOAL

OMMISSION.

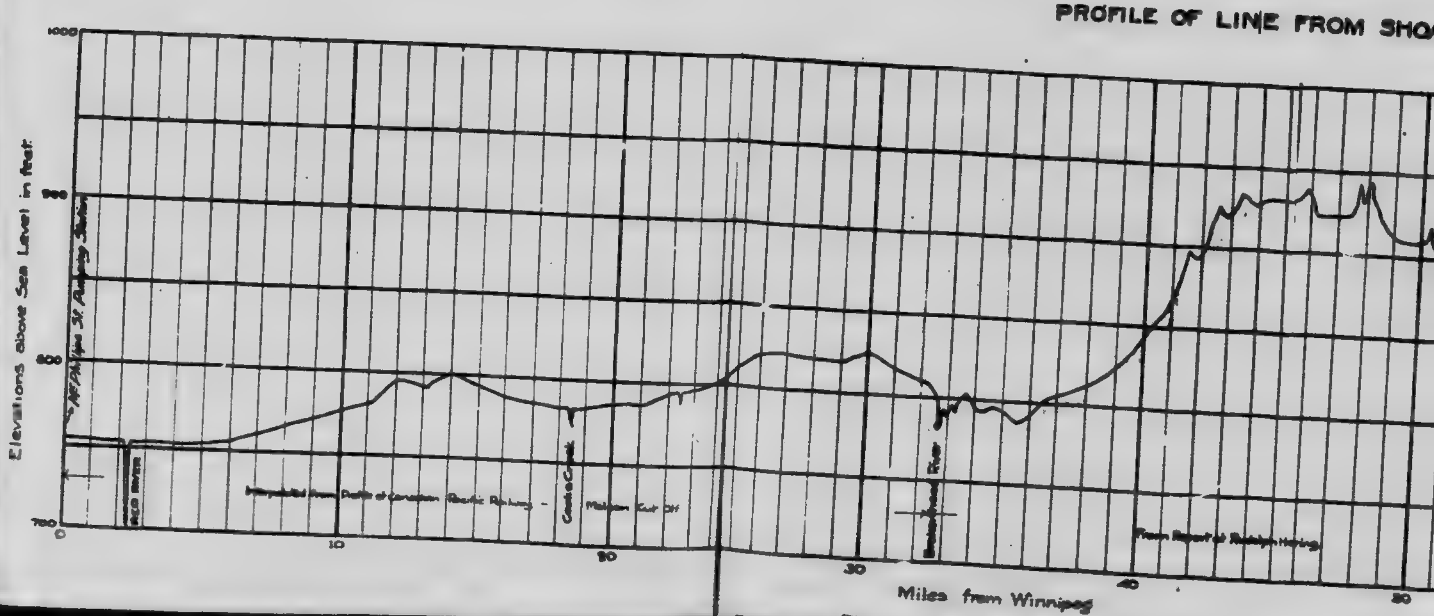
port of

S ENGINEERS

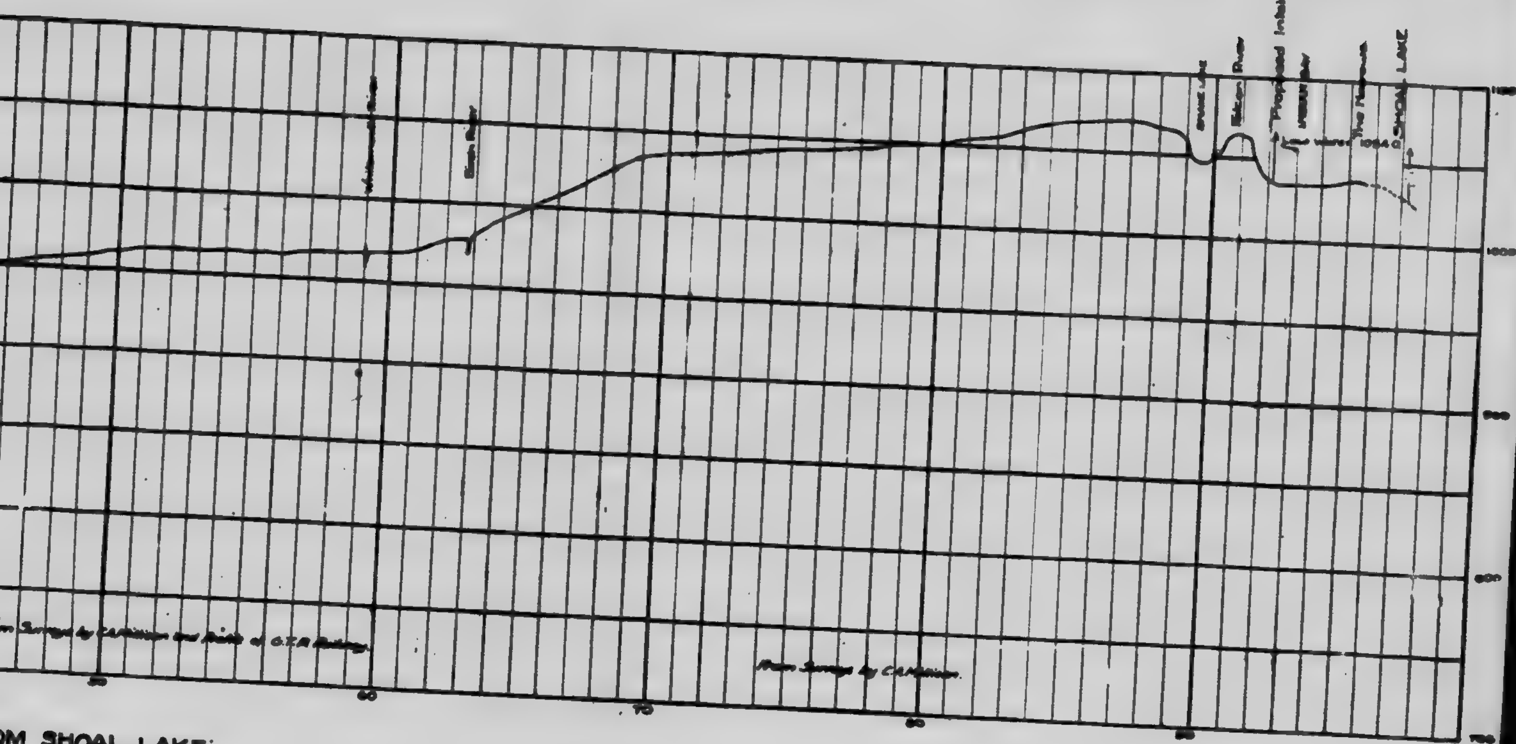
PLATE V.



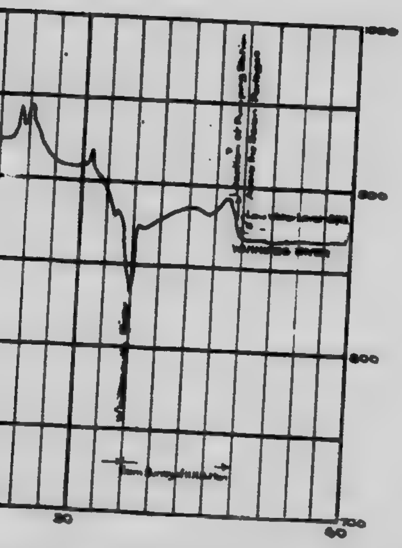
PROFILE OF LINE FROM SHO



PROFILE OF LINE FROM WINNIPEG RIVER.



OM SHOAL LAKE



WINNIPEG

WATER SUPPLY COMMISSION.

To Accompany Report of

BOARD OF CONSULTING ENGINEERS

James H. Fuertes,
R.S. Lea,
J.E. Schwitzer,
George C. Whipple.

August 28, 1907.

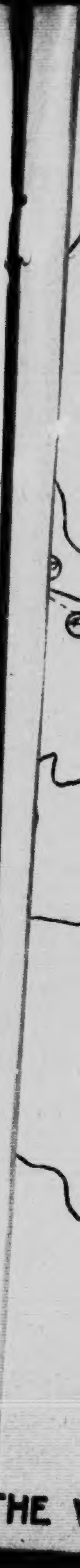
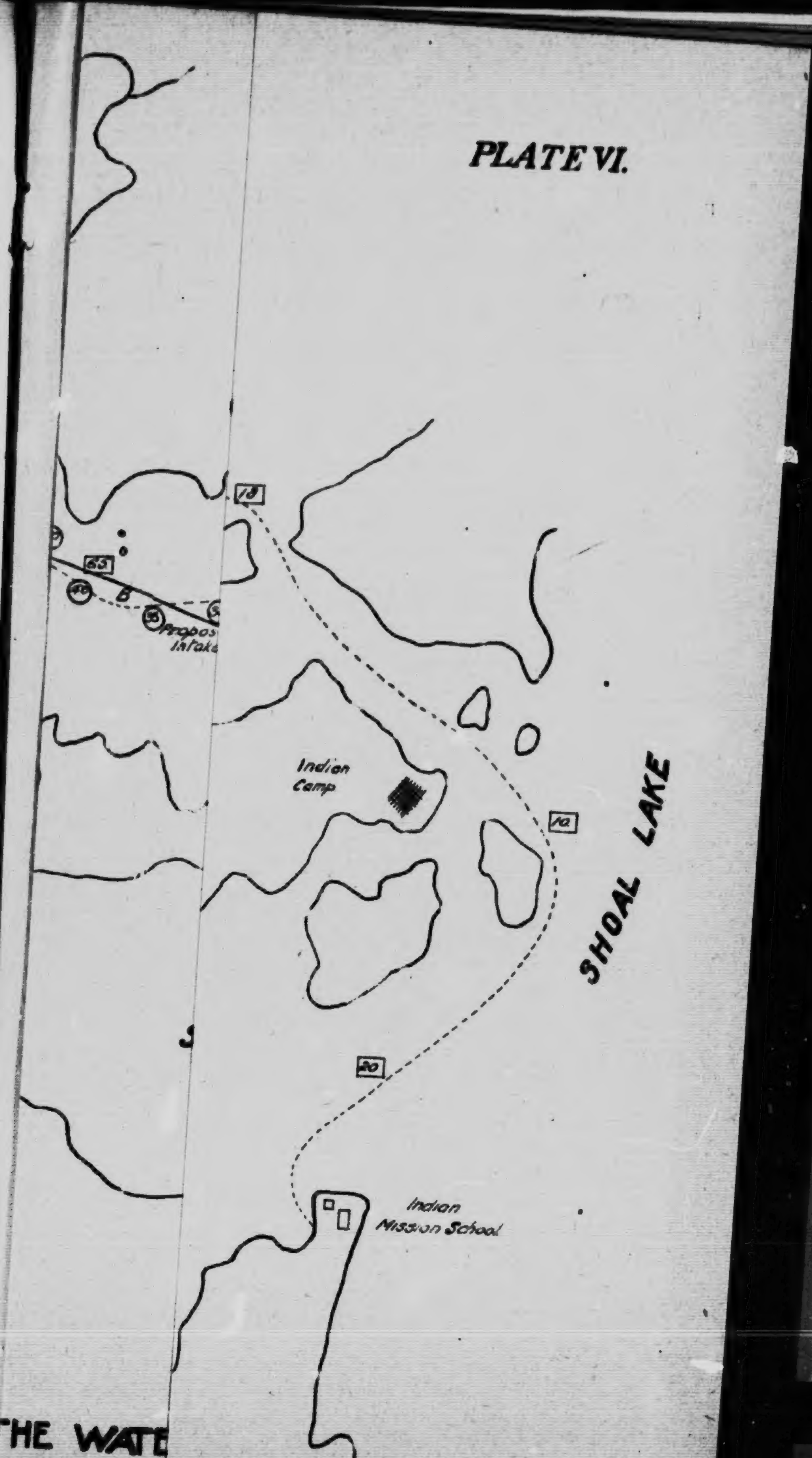
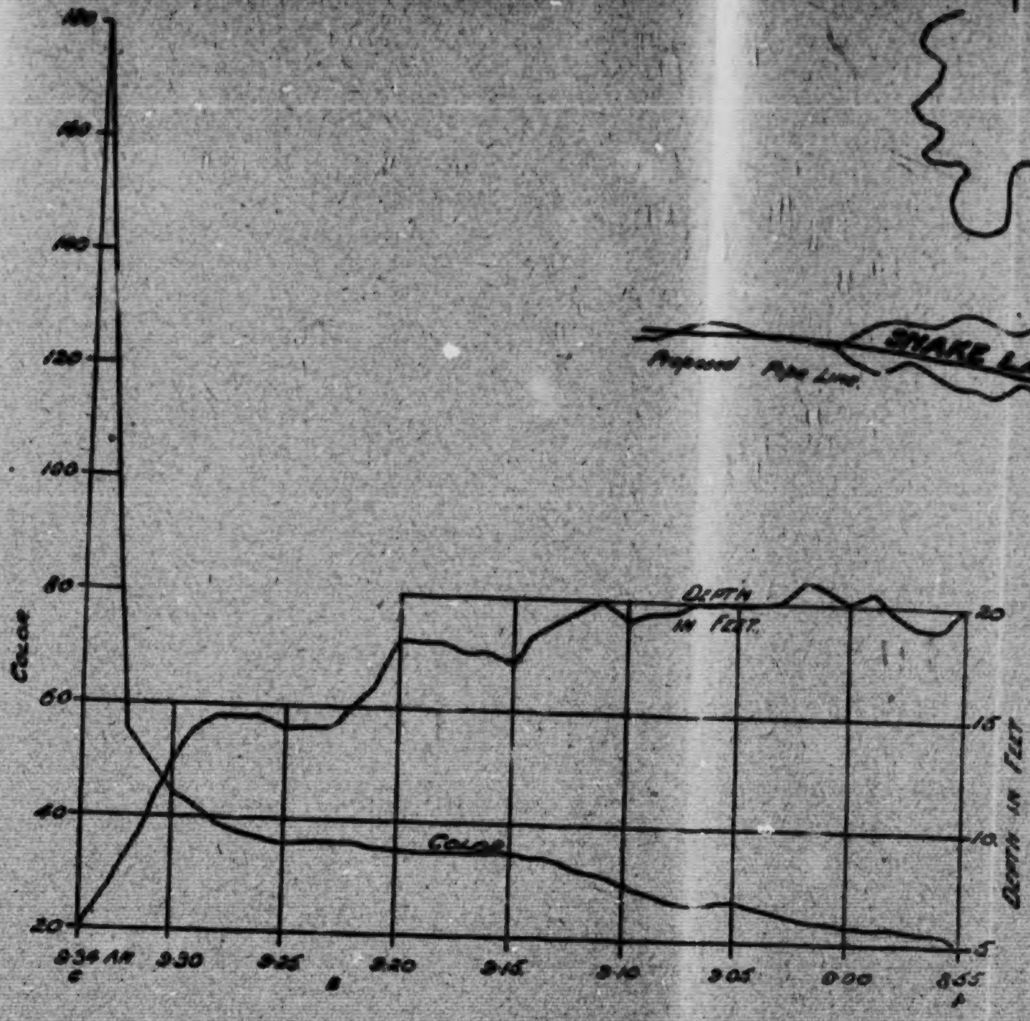
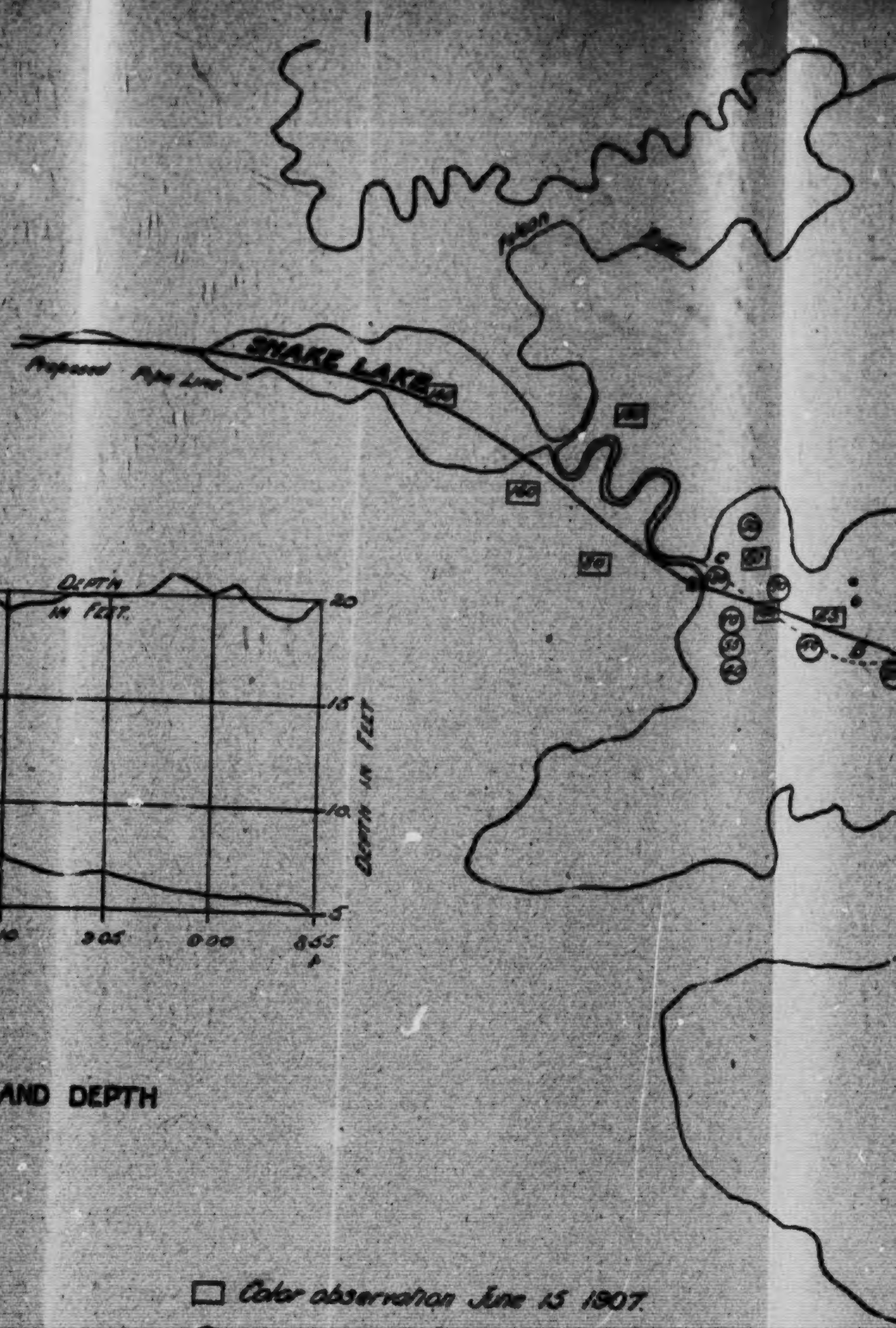


PLATE VI.


18
65
B
Intake
Indian Camp
10
SHOAL LAKE
20
Indian Mission School
THE WATE



OBSERVATIONS OF COLOR AND DEPTH



□ Color observation June 15 1907.

○ June 16 1907.

WINNIPEG
WATER SUPPLY COMMISSION

To Accompany Report of

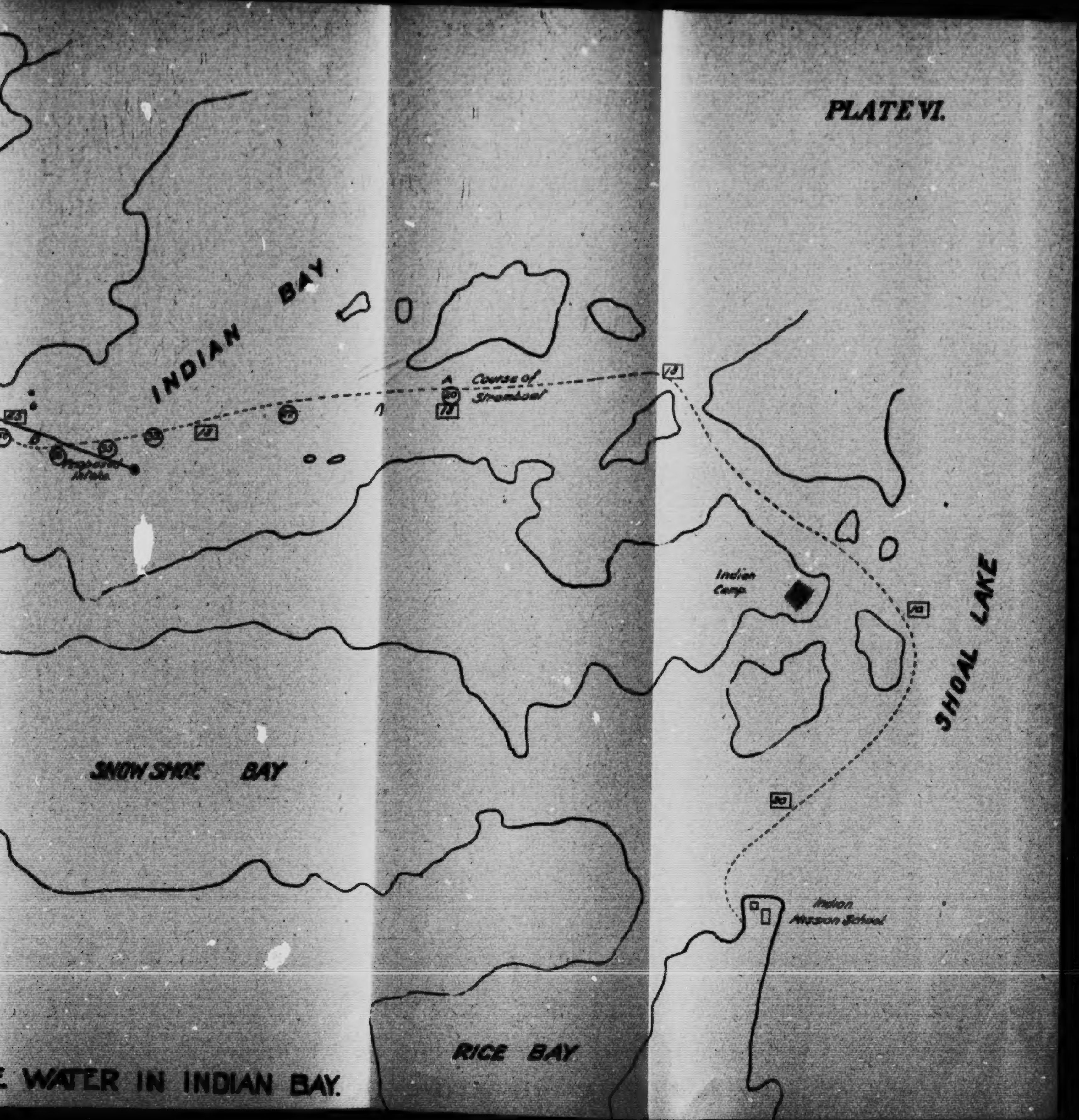
BOARD OF CONSULTING ENGINEERS.

James H. Fuertes
R. S. Lea
J. L. Schwitzer
George C. Whipple

August 23. 1907.

MAP SHOWING THE COLOR OF THE WA

PLATE VI.



E WATER IN INDIAN BAY.